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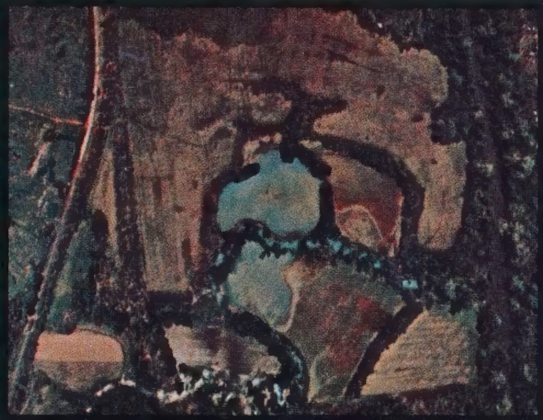
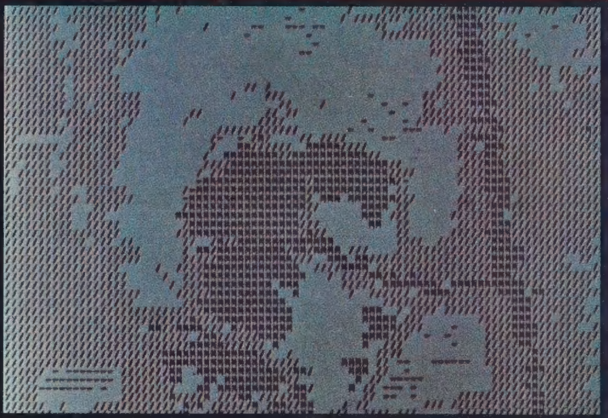
Proceedings

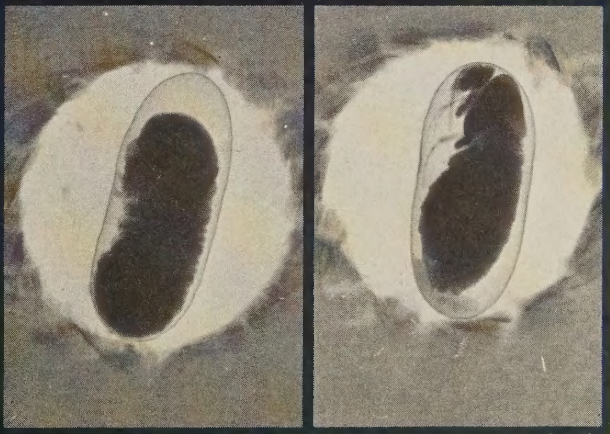
# FIFTH FOREST INSECT & DISEASE WORK CONFERENCE

# 1970





## a look ahead





DIVISION OF FOREST PEST CONTROL
Southeastern Area State and Private Forestry
U.S. Department of Agriculture Forest Service
Atlanta, Georgia 30309

# PROCEEDINGS

# FIFTH FOREST INSECT AND DISEASE CONTROL WORK CONFERENCE

Atlanta Cabana Motor Hotel
Atlanta, Georgia
February 17 - 19, 1970



Sponsored by
Division of Forest Pest Control
Southeastern Area, State and Private Forestry
U. S. Forest Service
1720 Peachtree Road, N. W., Atlanta, Georgia 30309

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Contents (Cont'd.)

William H. Clerk, Division of Forest Pest Control, explains the use of some of the photographic equipment used in survey work to a group of Atlanta University students.

# WELCOME TO FIFTH FOREST INSECT AND DISEASE WORK CONFERENCE

R. K. Smith [1/]

R. K. Smith, Assistant Area Director, Division of Forest Pest Control for the Southeastern Area, opens the conference.

Gentlemen, it is time to proceed with our Fifth Forest Insect and Disease Conference. It is good to see so many of you here this morning. Many of you have come long distances and delayed important work to participate on the program and to discuss some of the problems that we face in extending and protecting forest resources. With this group I am sure we will have a productive meeting.

The theme of our conference is, "A Look Ahead". It was chosen on the basis of your interests as expressed in the replies to our questionnaire as to timely subjects that should be included on the agenda. Replies indicated that the general objective of this conference should be to bring together the experts in the field of forest insect and disease control and through presentations, participation on the program, and visitations during the conference, explore and evaluate recent technological advances for use and adaptation to meet challenges ahead. Seldom does a week go by that I don't hear of or see a new method that

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1/ Assistant Area Director, Division of Forest Pest Control, State and Private Forestry, Forest Service, Atlanta, Georgia.

someone is using that is a better way of doing a job, perhaps more effectively than anywhere else. I hope there will be a really good interchange of information while you are here.

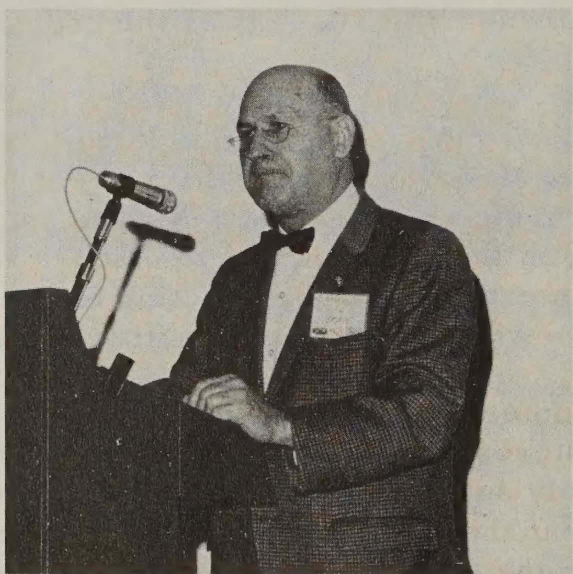
A proceedings of the presentations made at the conference will be prepared and those attending will receive a copy. Should you desire additional copies, please so indicate on the mimeograph sheet that you received when you registered. If we can be of help in anyway while you are here, let us know.

We are most fortunate in having so many people with such high level capabilities and experience in attendance. We have an excellent program and with the participation of the people that are in attendance, I am sure all will profit from this assembly.

To officially and personally welcome you and to get the conference underway, I would like to introduce D. A. (Doug) Craig, Director, Southeastern Area, State and Private Forestry.

## WELCOMING REMARKS

D. A. Craig [1/]



D. A. Craig, Director, Southeastern Area, State & Private Forestry welcomes delegates to the conference.

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1/ Area Director, Southeastern Area, State and Private Forestry, Forest Service, Atlanta, Georgia.

It is indeed a special privilege to welcome all of you to the Fifth Forest Insect and Disease Work Conference. It gives me a great deal of personal satisfaction to see the eagerness and willingness of so many people to take time out from their busy schedule to assemble here to consider the challenges and problems of pest control both now and in the future. Many different groups are represented here this morning, for instance I see people from industry, universities, State Forester organizations, Forest Experiment Stations, Federal agencies and many others. Many of you have curtailed important work and traveled long distances to be here.

When we consider the high caliber of the people appearing on the program, and the theme of the program, it isn't too surprising that you are here. We hope that you will all profit from your attendance.

With forest management operating in the highly complex field that exists, we need to increase our efforts to reduce losses to merchantable timber and to growing stock. This is not going to be an easy task in this space age when the main topics of conversation are computer programming, environmental contamination, hard pesticides and orbiting satellites. The pest control job is very complex involving many of the biological sciences. We realize that there are areas in which voids in our knowledge exist. The complexity of the forest pest problems, coupled with the urgency to reduce losses and harvest more timber, emphasizes the timeliness of this meeting.

The technological prospects for the future are limited only by one's imagination. Initial detection will soon be performed by orbiting vehicles equipped with a variety of instruments to keep us informed of conditions of our forests. With more ecological data available, evaluations of potential damage will become more meaningful. Through the use of computers we will be able to construct realistic models of our pest population and so be able to predict with a great deal of accuracy what a given pest will do under certain environmental conditions. Long-term weather forecasts will improve the accuracy of our predictions enormously. There is renewed interest in weather modification which would enable us to control our environment and perhaps pest outbreaks to a limited degree.

Pest Control is not an entity in itself, but an integral part of our forest management program. Without proper forest management, forest pest control will never emerge from its present cut and spray program, regardless of how sophisticated our detection and evaluation methods are; and emerge we must, because our potential pest problems are too great to be handled by nineteenth century methods.

It is becoming increasingly obvious that our pest control program must become a pest management problem. Pest management is one of a number of more or less analogous terms that refers to management of aspects of the environment in ways that will benefit our interests. It consists of the intelligent management of pests and of their environment and the management by the people who devise or do that managing. It consists of the prevention of pest attacks, primarily by the control of pest behavior, to prevent pests from attacking resources; and the control of pest numbers, to reduce the intensity of attack. To achieve this will require the management of the entire ecosystem in such a way as to minimize the favorable habitat available to the development of insect and disease pests. This will require the close cooperation of all landowners living within the system. We can't have some landowners carrying on proper management techniques and some not if we are to have a successful pest management program.

It has long been recognized that perhaps the biggest problem facing southern forestry is the large number of small landowners, many of whom lack the time, money and motivation to properly manage their woodlands. These people must be made to realize the economic loss in their unmanaged wood lots both to themselves and their community and hence the necessity for proper forest management of the entire ecosystem.

In accomplishing this, industrial, state and federal pest control organizations must be strengthened and must work closely together. Up-to-the-minute knowledge of our pest population is essential if we are to manage them most effectively. Until the satellites I mentioned become a reality, state and industrial forestry programs must assume more of the responsibility for initial detection. Systematic surveys should be carried on periodically over entire states before epidemics are noticed on the ground. The relatively new technique using aerial color infra-red photographs could be used to great advantage in this type of survey. While much work remains to be done before this technique is perfected, even in its present state of development it still offers the most sophisticated and statistically sound survey system available.

Once detected we must evaluate the biological potential of the pest involved. To do this we must make more effective use of the ecological data available to us. We need to get research information disseminated to the land manager. Predicting what damage a pest will cause is still an art, and a rather primitive one at that, but the degree of artistry can be reduced through the use of sound statistical procedures some of which are available today but many more of which we need to develop. Effective use of presently available automatic data processing techniques would allow us to consider more of the almost limitless variables involved in evaluating not

only the potential of the pest, but also its effect, and the effect of control measures on the whole ecosystem.

We can do a great deal to lessen the effects of applied control. Everyone in this room is familiar with the public concern over the use of insecticides. Granting the fact that very little is actually used in the forest, we can do a lot more to lessen their use by recommending less toxic, less persistent, more specific low-volume chemicals. Effective pest management also requires effective management of associated organisms, particularly parasites and predators. By careful manipulation of the environment and judicious use of insecticides we could do much to maintain higher populations of these beneficial insects.

Pest management must include and emphasize the maintenance of a quality environment for man. Pollutants of airsheds over forested areas must be detected, identified and their extent and intensity defined. It must further provide assurance that there will be no pollution of soil or water in such management.

Considerable research and effort must go into a program of forest pest management. Close cooperation between the research and control organizations are essential if we are to make rapid progress. As new information and concepts are developed they must be tested in the field, and if worthwhile, put to use quickly. The time lag between the release of research and practical use must be reduced, by the use of more expedient means of research dissemination.

In closing, I would like to emphasize that the concept of pest management is not new. Agriculture has, on a limited scale, used such a system very effectively in the past, as have we. But I would hope that we would make a more conscious effort at developing such a program for all our pests. This is not something that we must wait for future technology to develop, we have the knowledge to begin today.

Seldom have we had so many high level people convened to deal with the problems involved. With the competency of this group, I am confident good progress will be made. We need to get acquainted with all the people concerned and discuss the many problems involved. These groups working together and in full cooperation with each other are the ones who will provide the impetus for accelerated effort. With good free discussion and the opportunity to develop new approaches, I am sure you will have a most successful conference.

Again, welcome to Atlanta. If there is anything we can do to make your stay more pleasant or profitable, let us know.

# A LOOK AHEAD

R. B. MacDonald [1/]

R. B. MacDonald, Remote Sensing Specialist from Purdue University delivers the keynote address entitled "A Look Ahead".

Lord Kelvin stated, "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of Science, whatever the matter may be".

Certainly as the world's increasing population demands more and more of the earth's resources and spews out ever increasing quantities of waste materials, the need for management of earth resources and control of the environment becomes even more mandatory. If man expects to come to understand his ecosystem, to be able to plan wise resource development programs, to effectively manage the use of resources and to maintain a quality environment; he needs to be able to observe and more importantly measure his resources and his environment. It is only then that man can hope to understand his ecosystem so he can wisely preserve and control it.

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1/ Technical Director, Laboratory for Applications of Remote Sensing, Purdue University, Lafayette, Indiana

Remote sensing is the science and art of acquiring information about material objects from measurements made at a distance without coming in physical contact with the objects. All such measurements, which I will be discussing, are characteristic measurements of the electromagnetic energy radiated by such objects (Figure 1).

All materials emit electromagnetic energy for several reasons. As you are aware, physical bodies at any temperature above absolute zero (zero degrees Kelvin) radiate energy in the form of electromagnetic waves. Energy so radiated is a function of the temperature and nature of the surface of a body. The nature of radiating surfaces is described by their emissivities and is a function of the physical and chemical properties of particular materials.

The earth's surface is roughly $300^{o}$ and consequently emits energy at longer wavelengths than visible red light. These waves are called infrared, meaning beyond the red. At $300^{o}$K the earth's surface radiates most of its energy at wavelengths between 2 and 15 microns. Another reason that objects radiate energy is due to the reflective properties of their surfaces. A certain portion of incident solar energy is immediately re-radiated or is said to be reflected away from objects at the earth's surface. This energy is a function of the reflectance of an object's surface and is again related to the physical and chemical properties of different materials.

Sensors which measure the energy naturally radiated by objects are referred to as passive remote sensors. Rather than rely on incident energy from the sun, active remote sensors such as radar first transmit energy to the object and measure the portion which is reflected back.

Any object or scene is made up of small radiating elements (Figure 2). The resolution of the sensor being used determines the smallest size individual radiator which can be discerned by that particular sensor. The sensor might be a human eye, camera, spectrometer, or radar.

While such sensors have radically different physical appearances, they all perform much the same function. They detect and measure characteristics of electromagnetic energy radiating from a scene. Even though sensors come in many forms, there are only four basic characteristics of this energy which can be measured. These are spatial, spectral, temporal and polarization characteristics

Why so many instruments? Why do they look so different? The number of instruments and their differing physical appearances are indicative of the many different interactions which occur between materials and elec-

tromagnetic energy of different frequencies. For example, glass is transparent to visible frequencies and opaque to longer wavelength infrared. Sensors are designed to operate at widely differing frequencies. The kinds of measurements which can be collected in any one region of the electromagnetic spectrum are few in number.

When a sensor measures the amount of energy being radiated at an instant of time from the smallest resolved radiators as a function of their relative location in a scene, the sensor is measuring the spatial characteristics of energy radiating from a scene. When a sensor measures the amount of energy being radiated at an instant of time from the smallest resolved radiators as a function of frequency or wavelength, the sensor is measuring the spectral characteristics of energy radiating from a scene. If measurements of spectral or spatial characteristics are made at different times as a series then temporal characteristics of the radiated energy are being measured.

The relationships which exist between measurable characteristics of remotely sensed energies at different parts of the spectrum and the temperatures, emissivities and reflectances of the encountered complex radiating scenes must be understood. In addition, one needs to know the relationships which exist between the various physical and chemical properties of these complex radiating scenes and the composite effects of the temperatures, emissivities, and reflectances of their component parts.

The researcher must learn enough to develop a deterministic or statistical model relating these measurable energy characteristics to physical and chemical properties of the scenes within the geographic area of interest (Figure 3). These models must be developed before data can be collected by remote sensing.

Photographic emulsions, photomultiplier tubes and solid state detectors can all be utilized in remote sensors to directly record electromagnetic energy occurring at frequencies from ultraviolet through the visible into the reflective infrared region and out to one or two microns. Within this frequency region, photomultipliers and solid state detectors can measure amounts of energy more accurately than can film. While films are extremely sensitive and have very high resolution (many line pairs per millimeter), they are difficult to calibrate and control. Beyond one or two microns, film emulsions are not sensitive and solid state detector materials must be relied upon. Such detectors are sensitive throughout the thermal infrared interval to beyond 15 microns.

Film emulsions have historically been used in a qualitative capacity requiring complex human interpretation routines to extract their informa-

tional content. However, we expect in the future to learn how to calibrate and control these emulsions so that they can be used to provide some quantitative measure of spectral energy adequate for certain applications. Calibrated black and white panchromatic film can provide a quantitative measure of spectral energy. Color film emulsions cannot provide such measurements; they provide measures of color. Recognition of objects on a basis of color can be quite different from recognition on the basis of spectral energy characteristics. All materials which have the same color do not necessarily have the same spectral emission properties.

So far little has been discussed about the data which can be acquired in the data acquisition phase of remote sensing and how these data may be related to the properties of the scene. The next important phase of remote sensing involves the steps required to reduce these data to information. Essentially one can utilize either human analysts, machines or a combination of the two. When there are large amounts of data needed or where great precision is required the concept of machine processing is an attractive one.

At LARS we have devoted ourselves to the specific task of marrying computers, humans and measurements instruments. Computers are not smart, but they are clever tools. This electromechanical slave will perform yeoman service if we supply it with proper data and proper instructions. Consider some of the advantages of a happy marriage of humans, computers and measuring instruments:

--Sensor operation can be faster and longer.
--More information can be derived in a given time interval.
--Comparisons of derived data with built-in reference standards, tolerances, or specifications are quicker by orders of magnitude.
--Proper provisions can be made for strict control of test operations by humans.
--Systematic errors due to operator bias are eliminated.
--Test data can be displayed automatically in any of several forms - paper or magnetic tape, punched cards, line printers or teletypewriters, automatic graphic recorders or X-Y plotters and others.

These factors become more important as the complexity of measurements increase and as we need to more quickly perform and interpret measurements.

In many applications, one needs to closely examine various possible measurements in search of those which may be handled in relatively small quantities. Optical processing techniques provide a promising

means for automatically processing spatial data in the future.

Alternatively, multispectral and time varying multispectral data are particularly amenable to machine processing (Figure 4).

Such data, therefore, are extremely attractive as are the remote sensors which can collect them (Figure 5). Computers can be programmed to recognize "patterns" within these data which are indicative of scene properties of interest. However, in this approach a human must properly program a computer to use pattern recognition techniques.

At LARS/Purdue, in our research, we are trying to learn the kinds of measurements required in various applications and how to best teach the computer to recognize meaningful patterns from these data (Figure 6). In order to teach the machine significant patterns, we have selected a relatively small amount of data from known areas which are representative of the different existing scenes of the region. These are referred to as training samples. The vast majority of data can then be processed automatically.

How does one go about applying all of this to an application of interest? In our soils applications research, we have been interested in examining the possible correlation that might exist between different properties of soil types and the spectral characteristics of their emitted and reflected radiation. In particular, we set out to study the effects of soil organic matter content on the spectral properties of soils. A 60 acre field was selected as the primary research area. Multispectral measurements were collected from an aircraft during a noon period in May of 1969 (Figures 7 and 8). At the time of the flight, the area had been prepared for seeding to corn and soybeans and so was void of surface cover. The surface soil patterns were typical of the gray brown podzals formed under forest vegetation. One hundred ninety seven one-kilogram surface soil samples (Figure 9) were obtained and taken to the laboratory to be analyzed for organic matter content by the Walkley and Black method. A soil map of the region (Figure 10) was also prepared as a part of the ground truth. The soil categories in the study area are given in Table 1.

The resolution of the airborne spectrometer is such that measurements were made of each 100 square foot area. Energy measurements were made in 12 frequency bands. Five levels of organic matter content based on the results of the laboratory analysis and other factors are given in Table 2. In total, 197 airborne measurements were selected from the areas of the soil samples and were used to train the computer to recognize these five levels. The number of training samples in each category are given in Table 2.

Table 1. Seven soil categories in study area, Dieterle Farm.

| |
|---|
| Del Ray Silt Loam |
| Fincastle Silt Loam |
| Kokomo Silty Clay Loam |
| Metea Sandy Loam |
| Russell Silt Loam |
| Toronto Silt Loam |
| Xenia Silt Loam |

Table 2. Five categories by percent organic matter and number of samples used in training.

| % Organic Matter | Number of Samples |
|---|---|
| 0 - 1.5 | 46 |
| 1.5 - 2.0 | 63 |
| 2.0 - 2.5 | 18 |
| 2.5 - 3.5 | 37 |
| above 3.5 | 33 |

After the computer was trained, it was instructed to classify all of the data collected over the area on the basis of its training and to printout the results (Figure 12). The particular spectral wavelengths chosen for the training analysis were:

0.46 - 0.48 microns
0.62 - 0.66 microns
0.80 - 1.00 microns
1.50 - 1.80 microns

Also, a soil mosaic was constructed from portions of each of the 197 surface soil samples to provide a model of the surface soil patterns (Figure 11).

It was observed that with refinement of the organic matter classes areas of severe to moderately severe erosion could be automatically identified.

As a part of the analysis, the average radiance level of each training sample was plotted against soil organic matter content for each of the 12 frequency bands (Figure 13). Linear regression analysis gave an r value of -0.74. It can be noted that the plotted data seems to indicate that a linear relationship may not be valid over the entire range of organic matter content. However, it appears that above 2.0 or 2.5 percent organic content, there may be a linear correlation with a much higher value.

The same training sets were then used to automatically classify all the points in an area 24 miles long and one mile wide. The results look very promising (Figure 14).

The results of this research are fast establishing the feasibility of using remote sensing and automatic processing to prepare maps by organic matter for large areas.

Generally, at LARS we have teams of scientists investigating applications of this remote sensing technology to situations involving the following natural materials:

1. Vegetation
2. Soils and geological formations
3. Water

The following is a description of some of our work and results at LARS, Initially, our investigations were directed toward the automatic identification of gross earth surface cover types (Figure 15). We have been able to map green vegetation, soil and surface water from data collected over central Indiana (Figure 16). Surface water has been identified with high reliability, even when it is not visible to the eye, and the areas covered by water are scarcely if at all discernable (Figure 17). However, combinations of spectral measurements beyond visible red permitted complete and automatic identification of all inundated areas. We are currently investigating the possibilities of sensing water quality. To date, spectral measurements have permitted the sorting of water in the White River outside of Indianapolis into a number of categories (Figure 18).

Since these data were collected for other purposes, no water samples to detect the content of the categories were collected at the time of flight. However, we hope in the future to be able to relate spectral categories to different chemical and organic properties of such water resources.

Some of our efforts are now being directed toward the uses of these techniques to measure the thermal characteristics of bodies of water. The

monitoring of these thermal characteristics is becoming increasingly important as the use of water resources becomes more intense.

As previously mentioned, our soils scientists are interested in the use of this technology to automatically map organic matter content.

Additionally, we have been successful to date in our attempts to quantify and map soil color measurements which as you know, can be related to other soil properties. The color patterns of the soils of the study area are shown in Figure 19, ranging from light to dark and including reddish yellow tones of subsoils in eroded areas. A computer derived map of the green vegetation, soil and surface water is shown in Figure 20. The computer was trained to map the soils into two categories, light and dark (Figure 21). Next the area was mapped in three categories of soil (Figure 22), and finally in six categories (Figure 23). In this work, training samples were selected on the basis of Munsell color notations of soil samples of the area and with spectral training samples selected on the basis of color photographs of the area.

We have concluded that just as theory predicts, one can produce a more refined map of the color characteristics of an area with fine quantitative spectral measurements than can normally be produced with photography.

Much of our total research has been directed toward developing a capability to automatically recognize vegetative species and important physiognomic characteristics of species. Our flight lines over Tippecanoe County enables us to collect data over 150 square miles of the 501 square mile area in the county (Figure 24).

While we have been interested primarily in automatically recognizing the major crops at critical stages of their growth -- corn, soybeans, winter wheat -- we have attempted to classify up to nine species. Figure 25 shows a photograph of a portion of a flight line in Tippecanoe. Computer printouts of the results of classifications of nine cover types are shown. The computer was also instructed to print only wheat, only bare soil and water, and only red clover. Figure 26 summarizes the recognition accuracies of this particular classification analysis.

We have also classified crops into categories such as row crops and cereal grains (Figure 27). Often this simpler recognition task can be accomplished with extremely high accuracy.

This last spring, the system was trained to recognize the spectral patterns of deciduous trees and programmed to analyze data from a selected

area. In the computer printout in Figure 28 the results are shown and are encouraging. Similarly, we have been able to map trees in orchards in Texas and elsewhere in the U.S. Mr. Joe Bell of your organization will go into more detail in applications of direct interest to your work which he has researched. As many of you may know, we had the pleasure of having Mr. Bell on our staff for a year.

Boresited cameras with different filters and proper controls can produce some quantitative measures of spectral energy adequate for certain applications. Apollo 9 carried four such boresited cameras. One was loaded with color infrared film and the other three with black and white film. Each camera had a different filter. This particular system was not calibrated in any way. I, therefore, consider these to be poor spectral measurements. However, NASA and USDA requested that we apply our LARS technology to these data.

The area of study is approximately 110 miles square. A microdensitometer was used to scan the photograph and digitize 1000 points per inch (20 line pairs per millimeter). These data were stored on magnetic tape. The computer was programmed to printout an alpha numeric gray scale presentation utilizing only every 6th point (4 line pairs/mm) (Figure 29). The important notion here is that every digitized point was in machine language and could be manipulated at will -- accurately and rapidly. The magnitude of data in such a complex scene was very great.

The three different black and white frames at 0.47 - 0.61 microns, 0.59-0.71 microns and 0.68 - 0.89 microns (visible and reflective IR) were similarly digitized and stored on magnetic tape. Since boresiting was not exact, the data was spatially registered electronically and fed to the computer.

A computer gray scale printout of the area at a full resolution of 20 line pairs per millimeter is shown within the black lines in Figure 30. NASA had collected considerable ground truth within an area marked by the dotted lines. Figure 31 is a gray scale printout at a full 20 line pairs per millimeter. The data were automatically classified into categories of green vegetation, bare soil, salt flats or surface water (Figure 32). Training samples were selected from the data on the basis of limited ground truth collected by NASA, and accuracies were evaluated from the results within "test areas". Again ground truth of the "test areas" made the accuracy evaluations possible. The results of this were quite amazing to us. All categories were classified better than 90 percent in the test areas.

In this fashion within hours a combination of man and machine can process data of an area some 10,000 square miles in size.

In conclusion, the success of this technique in applications is dependent on a successful blending of proper measurement devices, machine data processors, and informed humans. By an informed human I mean, one who has come to understand the relationships between the radiation characteristics of natural materials and their material properties. While the feasibility of these techniques have been established, there is an enormous amount of effort required to develop them to the point where we will realize the benefits they now promise. While I have little doubt that in the future these techniques will become an important tool, I have even less doubt that much effort by people such as yourselves, who have the problem will develop this to a point where it is an effective tool.

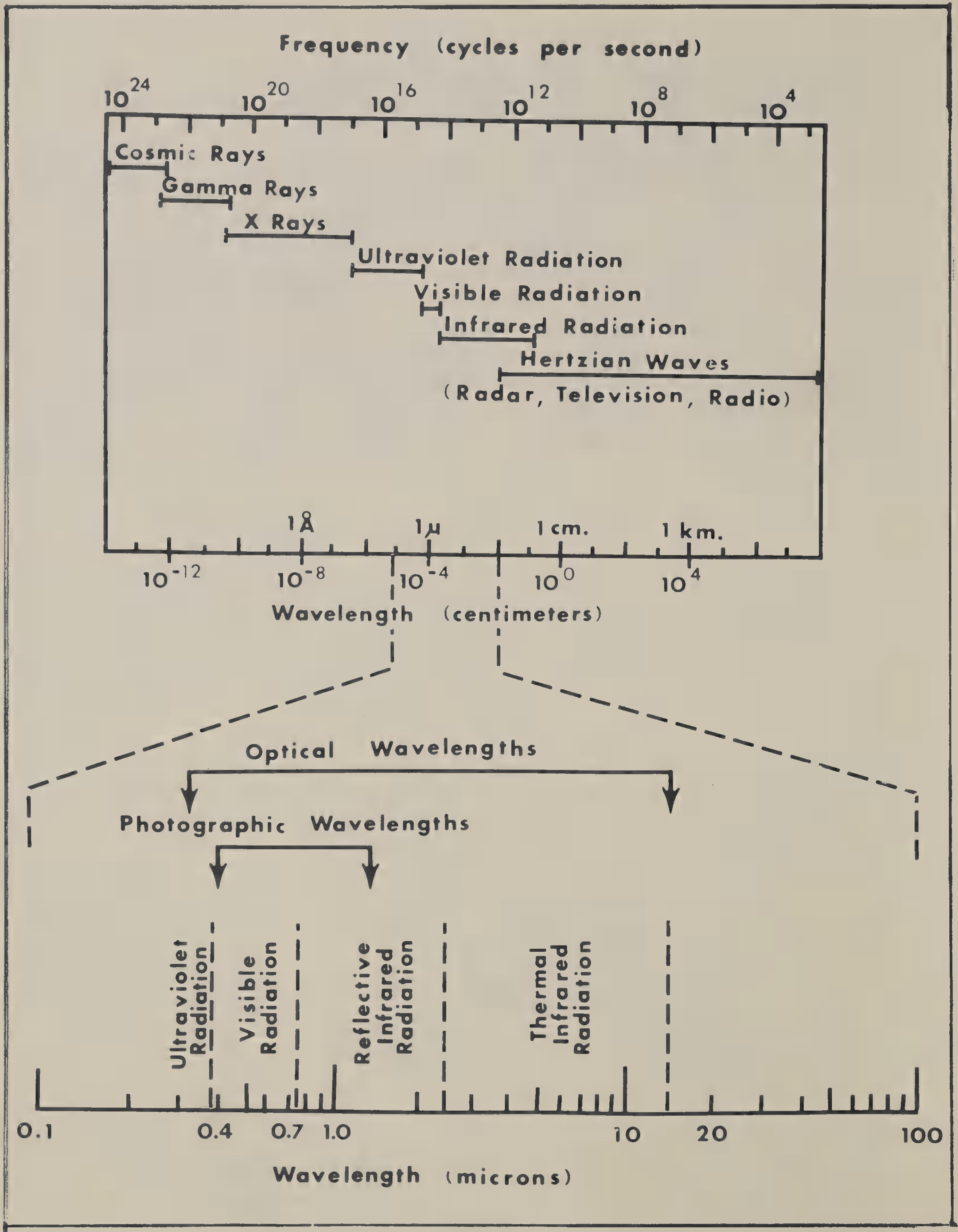


Figure 1. Electromagnetic spectrum.

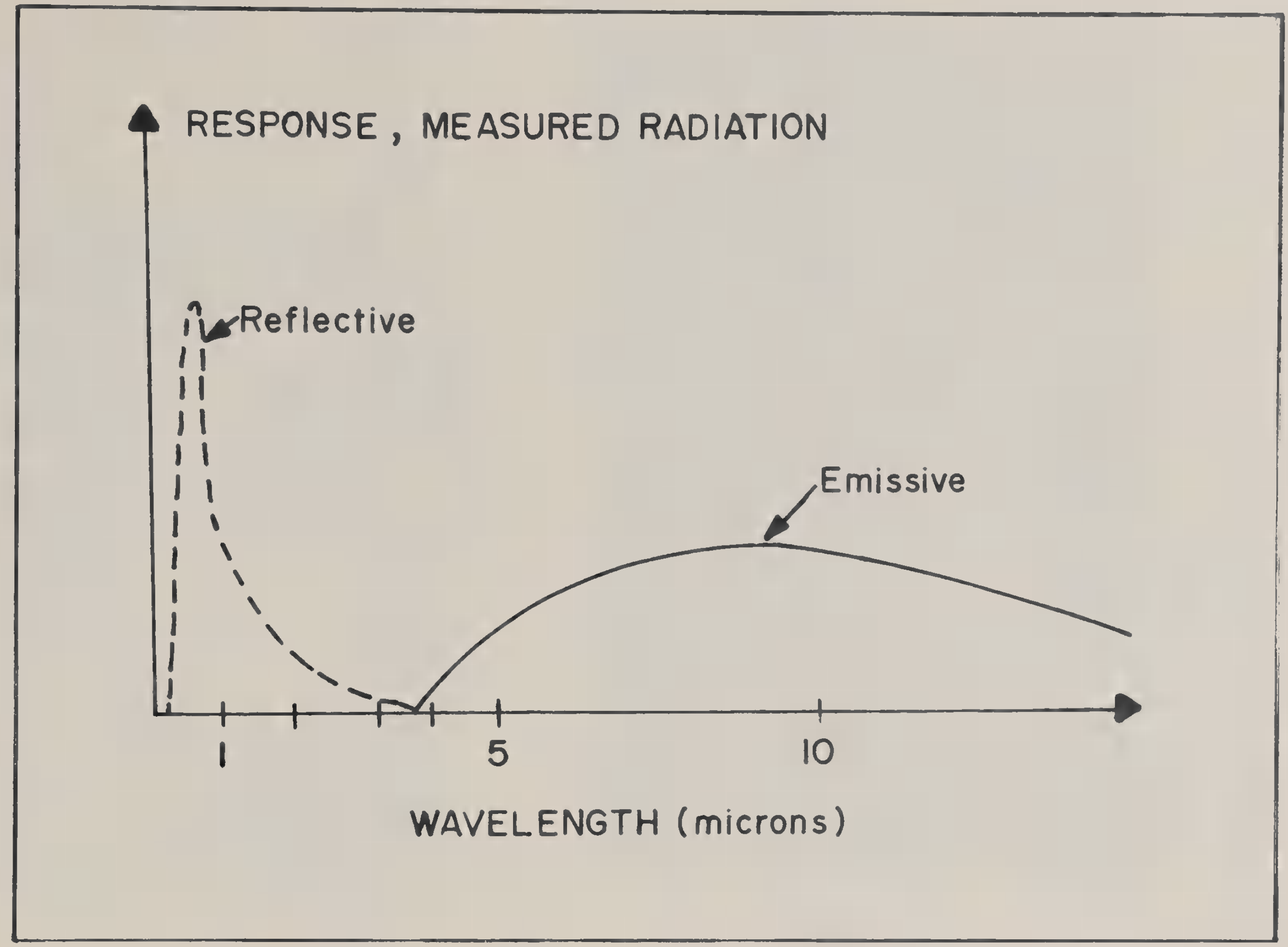


Figure 2. Frequencies where most naturally occurring energy is radiated.

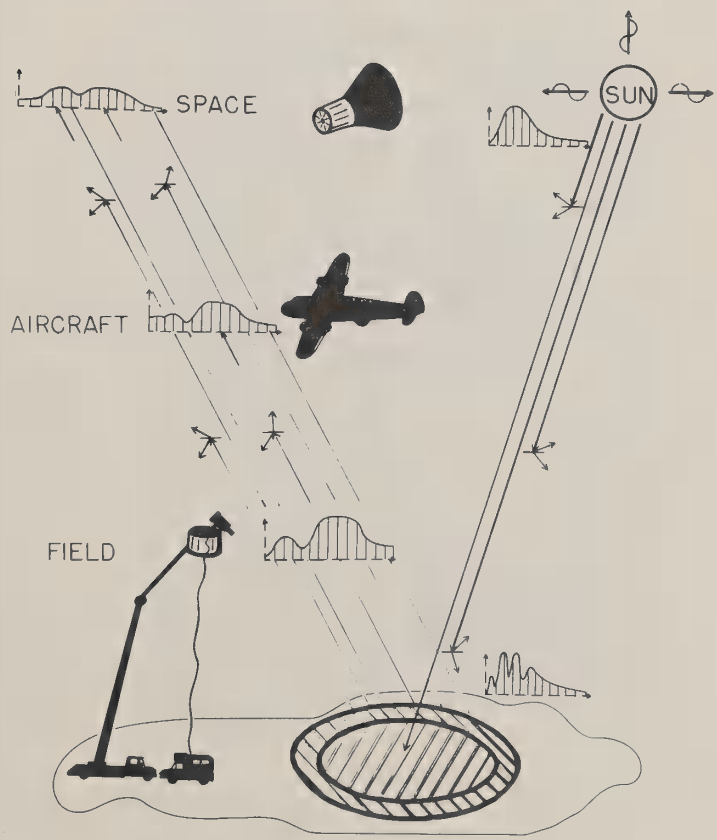


Figure 3. Remote sensing data can be acquired at different altitudes.


Figure 4. Images at different frequencies.

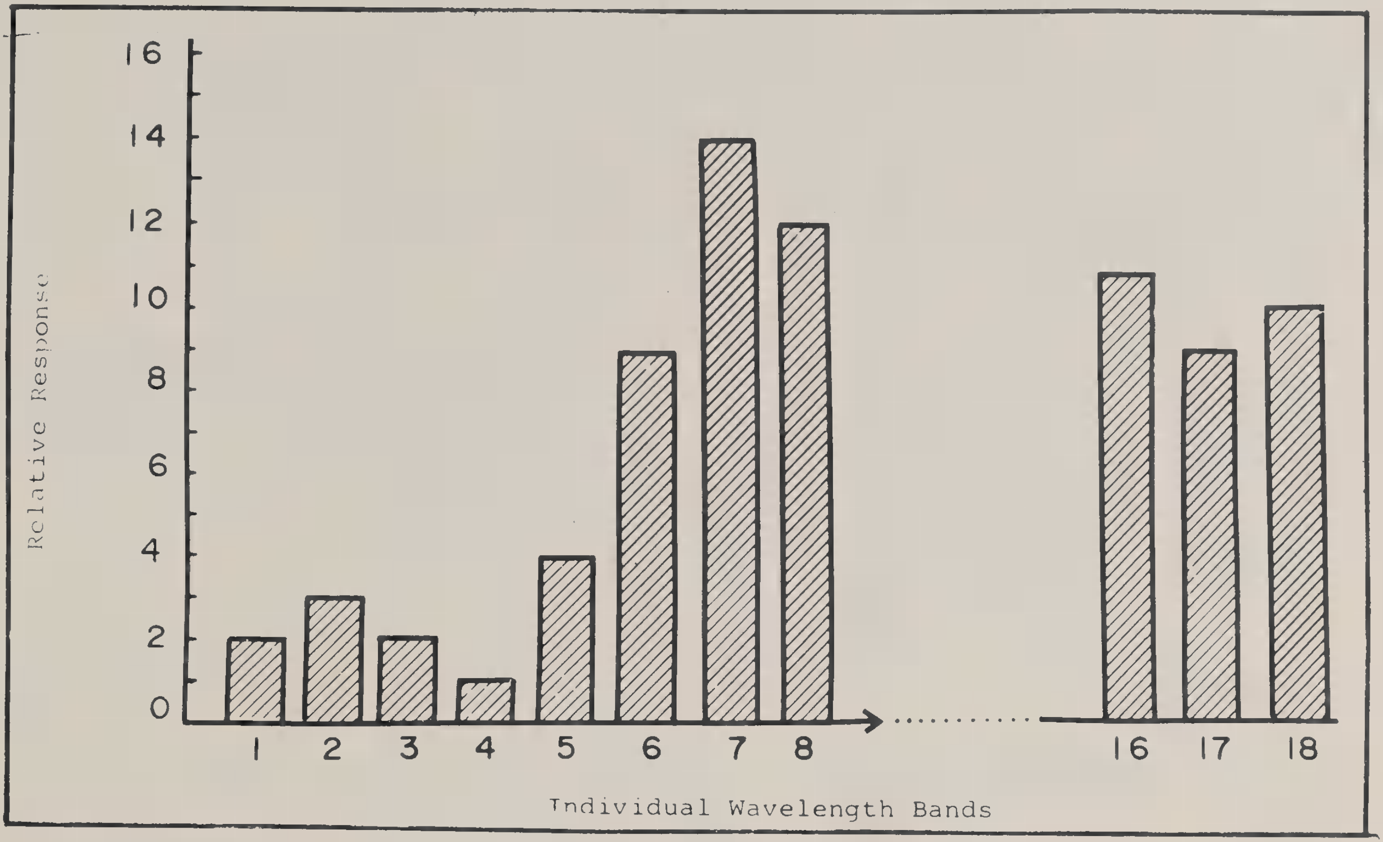


Figure 5. Theoretical multispectral radiation pattern.

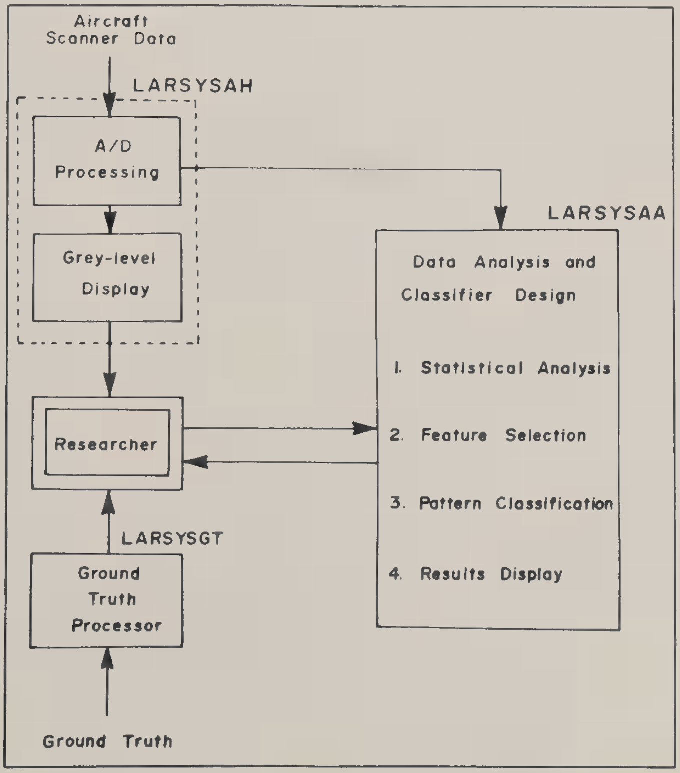


Figure 6. Outline of LARS data handling and analysis process.

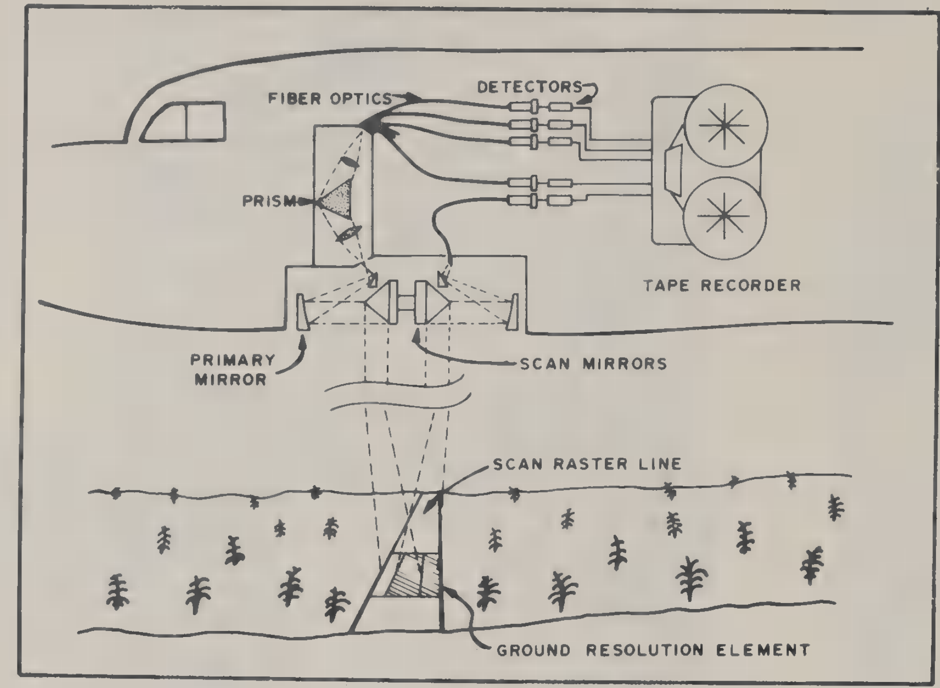


Figure 7. Illustration of data collection instruments utilized in remote sensing.

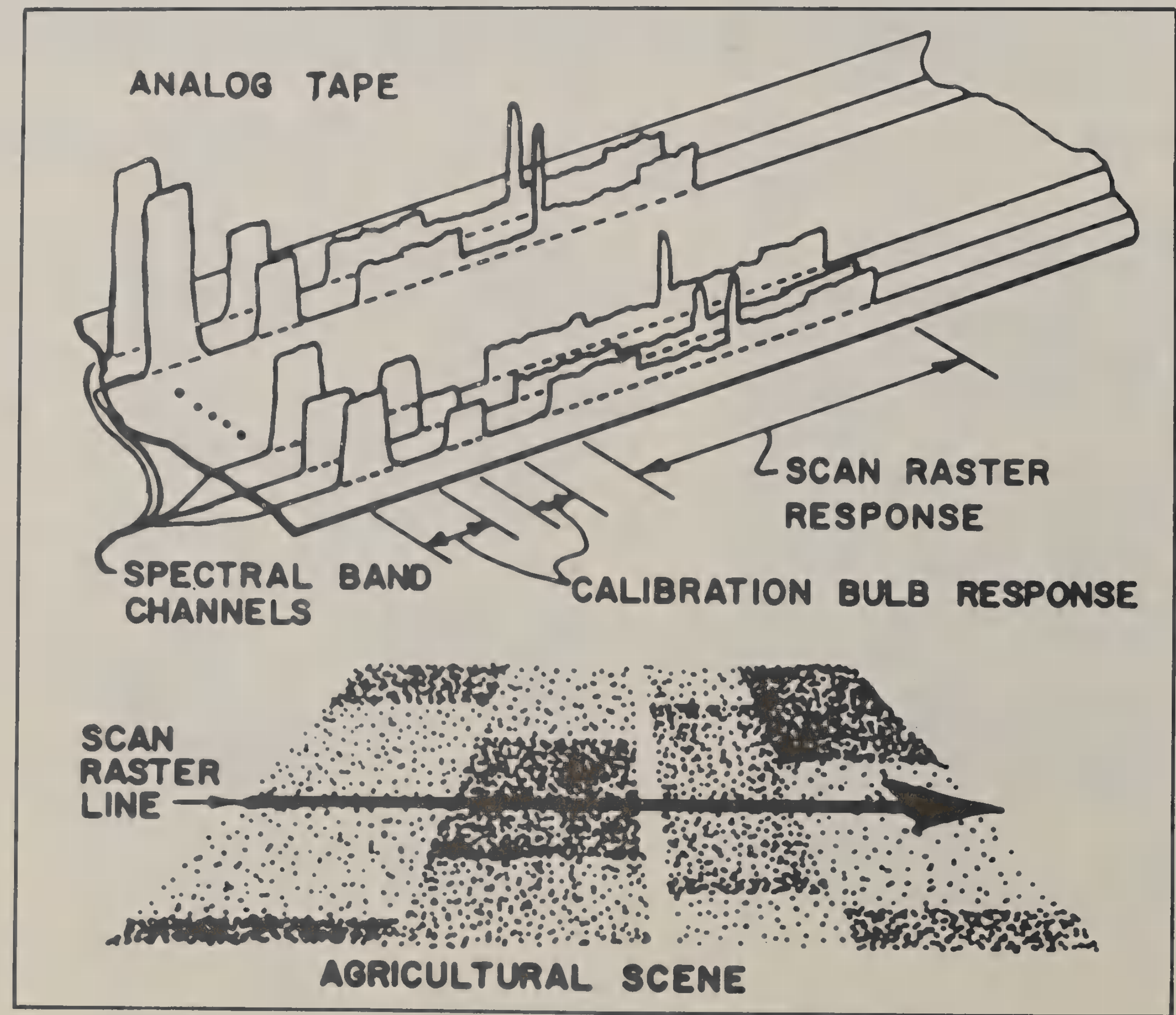


Figure 8. Illustration of analog tape recorder used to record the collected data.

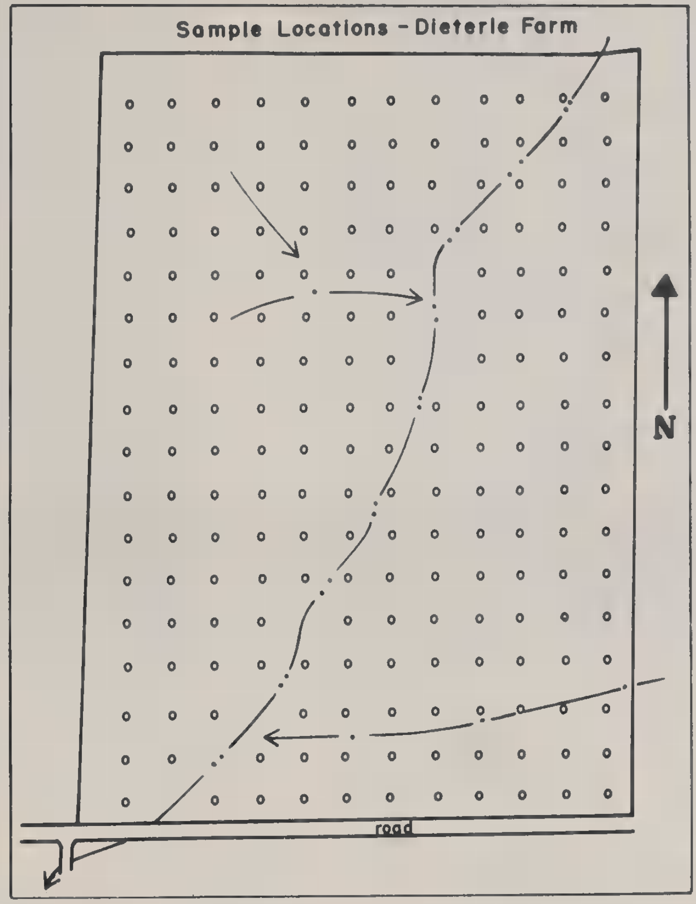


Figure 9. Location of the 197 samples which were collected.

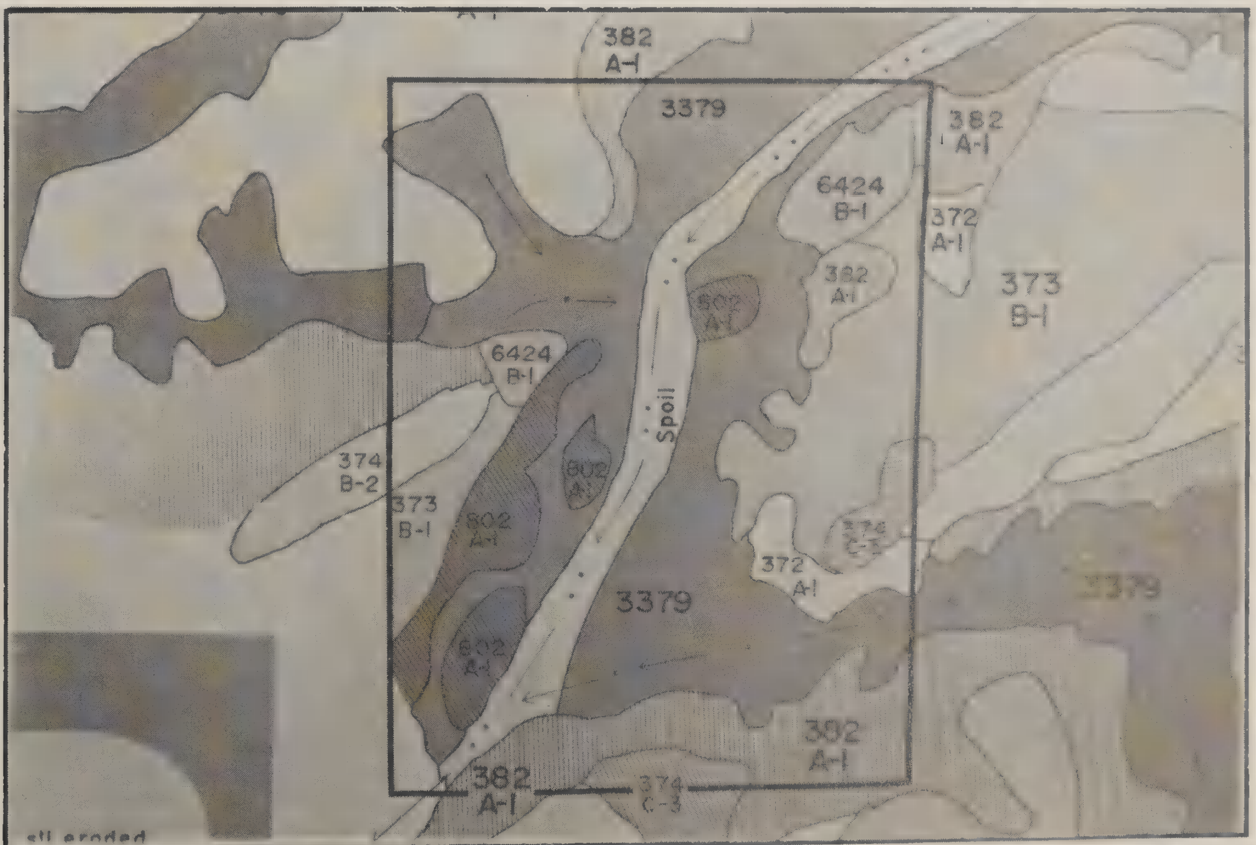


Figure 10. Soil map of the area where research was conducted. The outlined section is the same area as shown in Figure 9.

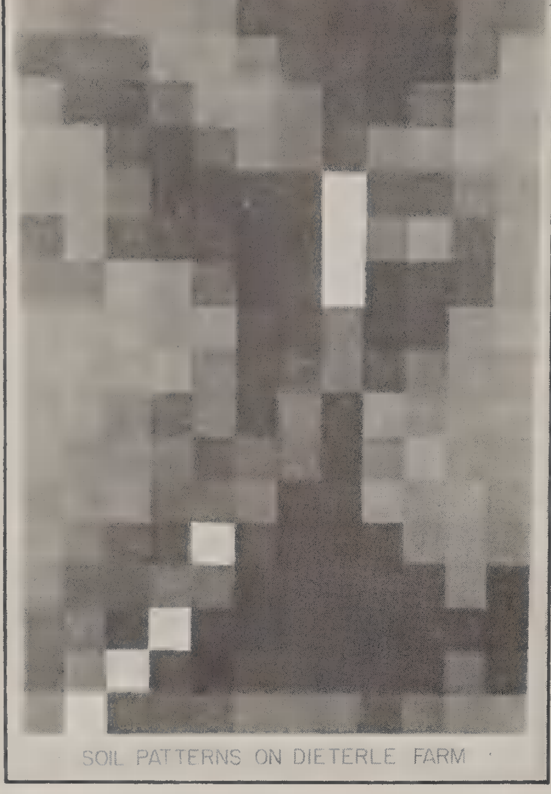


Figure 11. Mosaic of soil patterns in study area, Dieterle Farm.

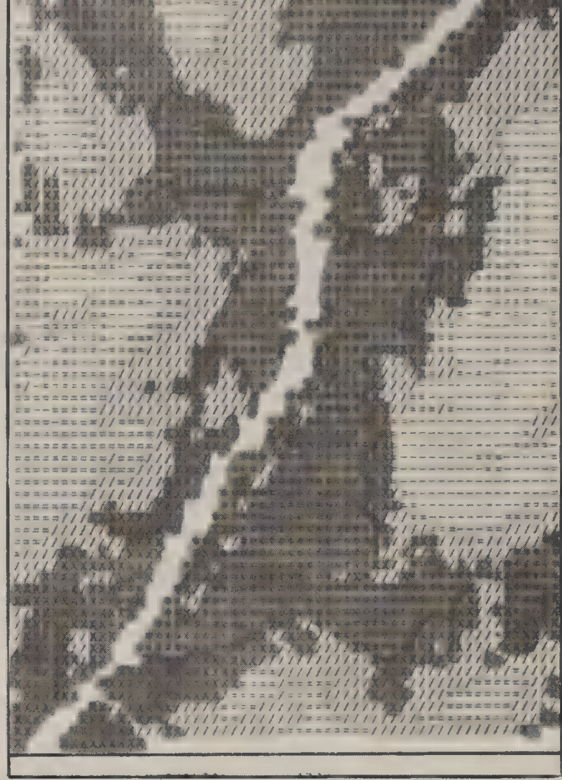

Figure 12. Computer map by organic content of the soil which was shaded manually.

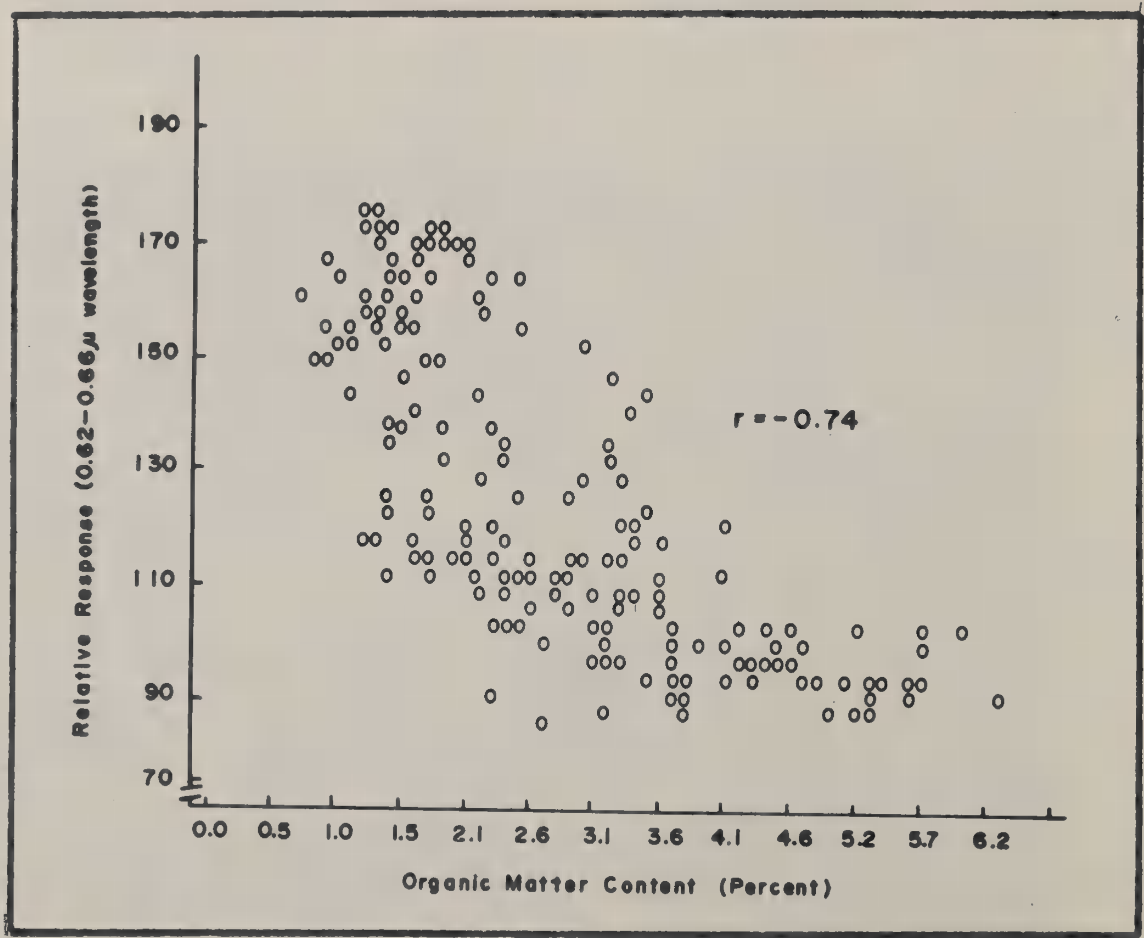


Figure 13. Correlation between average radiance level (relative response) and organic matter content for 197 soil samples in the 0.62-0.66 micron band.

LABORATORY FOR APPLICATIONS OF REMOTE SENSING
PURDUE UNIVERSITY
MAR 20,1970

CLASSIFICATION STUDY .. SERIAL NO. 319005914
CLASSIFICATION DATE .. MAR 19,1970

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| V | CL2 | 16.800 |
| / | CL3 | 16.800 |
| I | CL4 | 16.800 |
| F | CL5 | 16.800 |
| H | CL6 | 16.800 |
| Z | CLASS 7 | 16.800 |
| N | CL8 | 16.800 |
| * | CL9 | 16.800 |

FEATURES CONSIDERED

| CHANNEL NO. | SPECTRAL BAND |
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| 12 | 8.00 14.00 |

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TOTAL NUMBER OF SAMPLED POINTS = 3960

Figure 14. Computer map by organic content of the area around Dieterle Farm. Training samples were those from the study area.

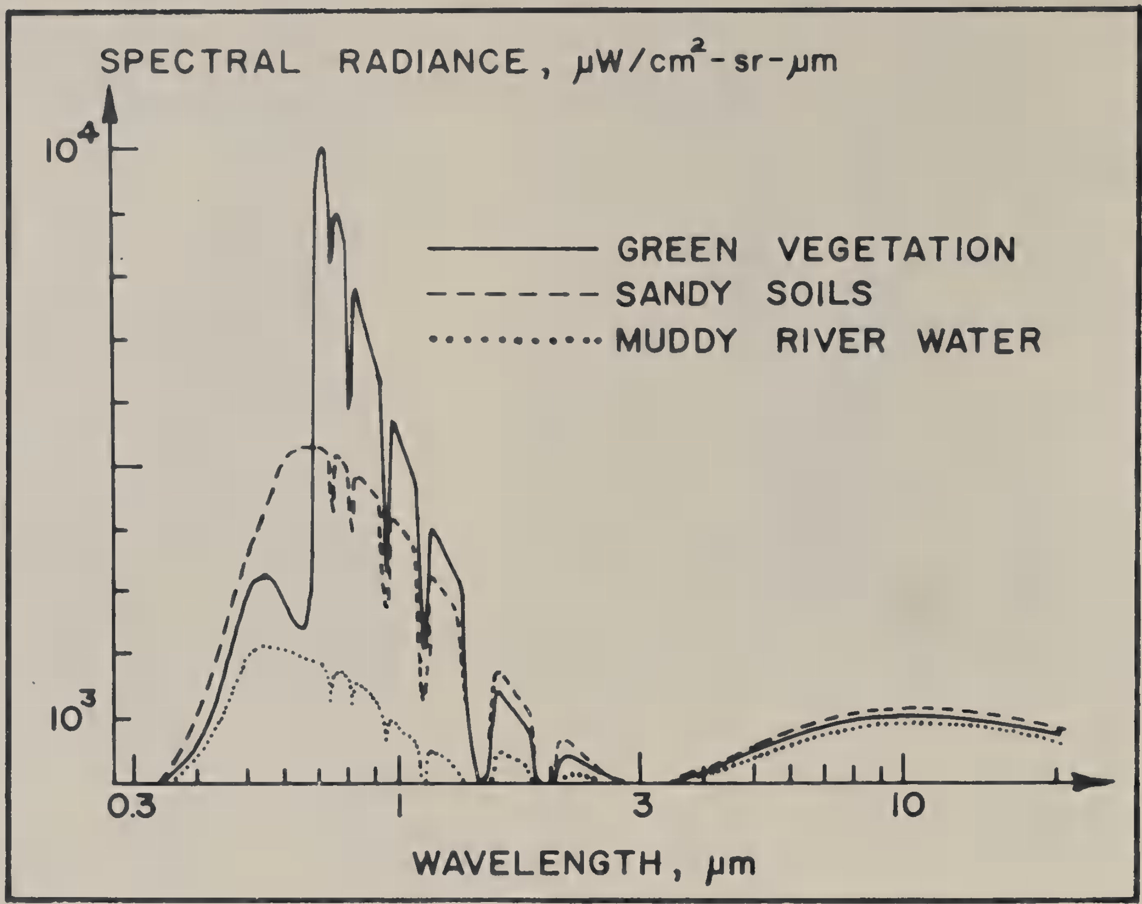
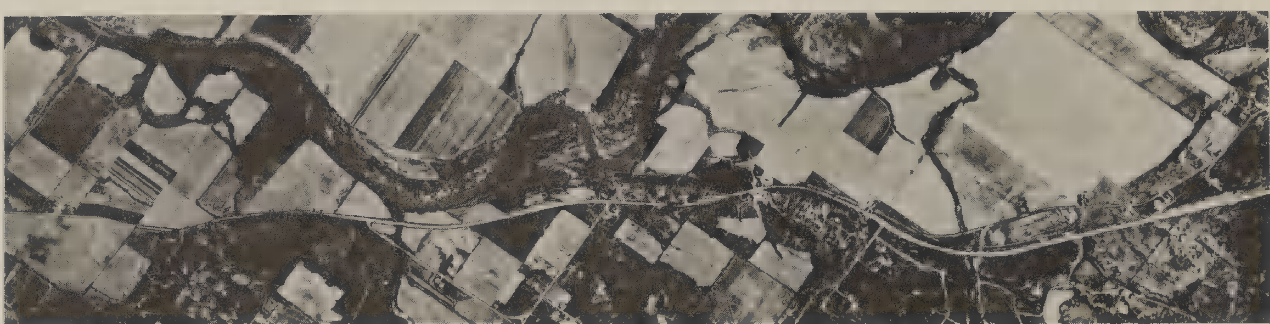



Figure 15. Spectral radiance response curves for green vegetation, soils and muddy river water.



Photograph

Figure 16. Photograph and computer printout of green vegetation, soil and water of an area in central Indiana.

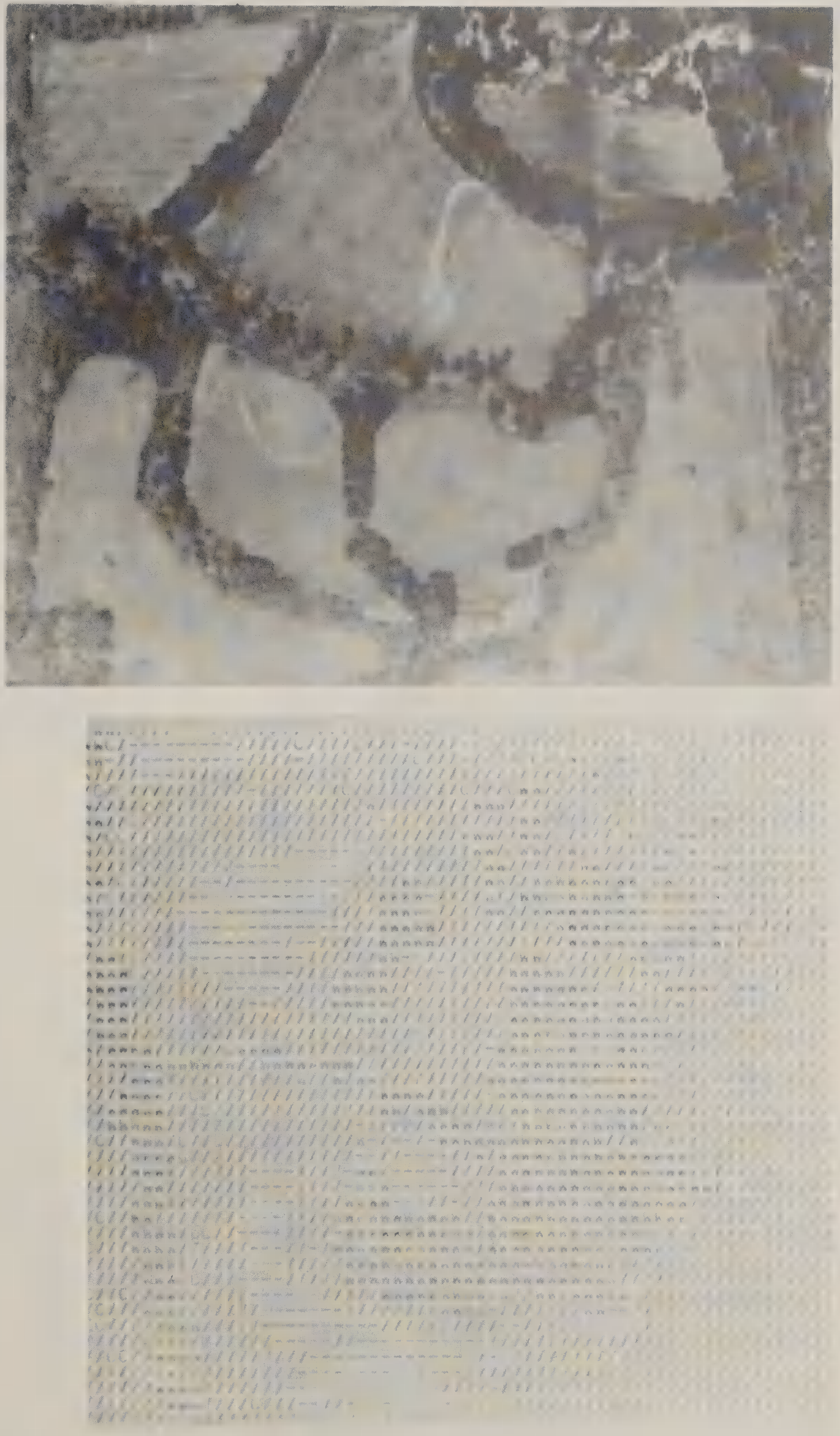


Figure 17. Photograph and computer printout of an area inundated with water.

Figure 18. Photograph and computer printout showing water classified into several categories of White River, Indianapolis.

Figure 19. Photograph of study area where different soil color patterns are visible.

Figure 20. Computer map of green vegetation (I), soil (-) and water (M) for area shown in Figure 19.

Figure 21. Computer map of the dark and light soil of the area shown in Figure 19.

Figure 22. Computer map of dark, medium and light soil of the area shown in Figure 19.

Figure 23. Computer map of six soil categories of the area shown in Figure 19.

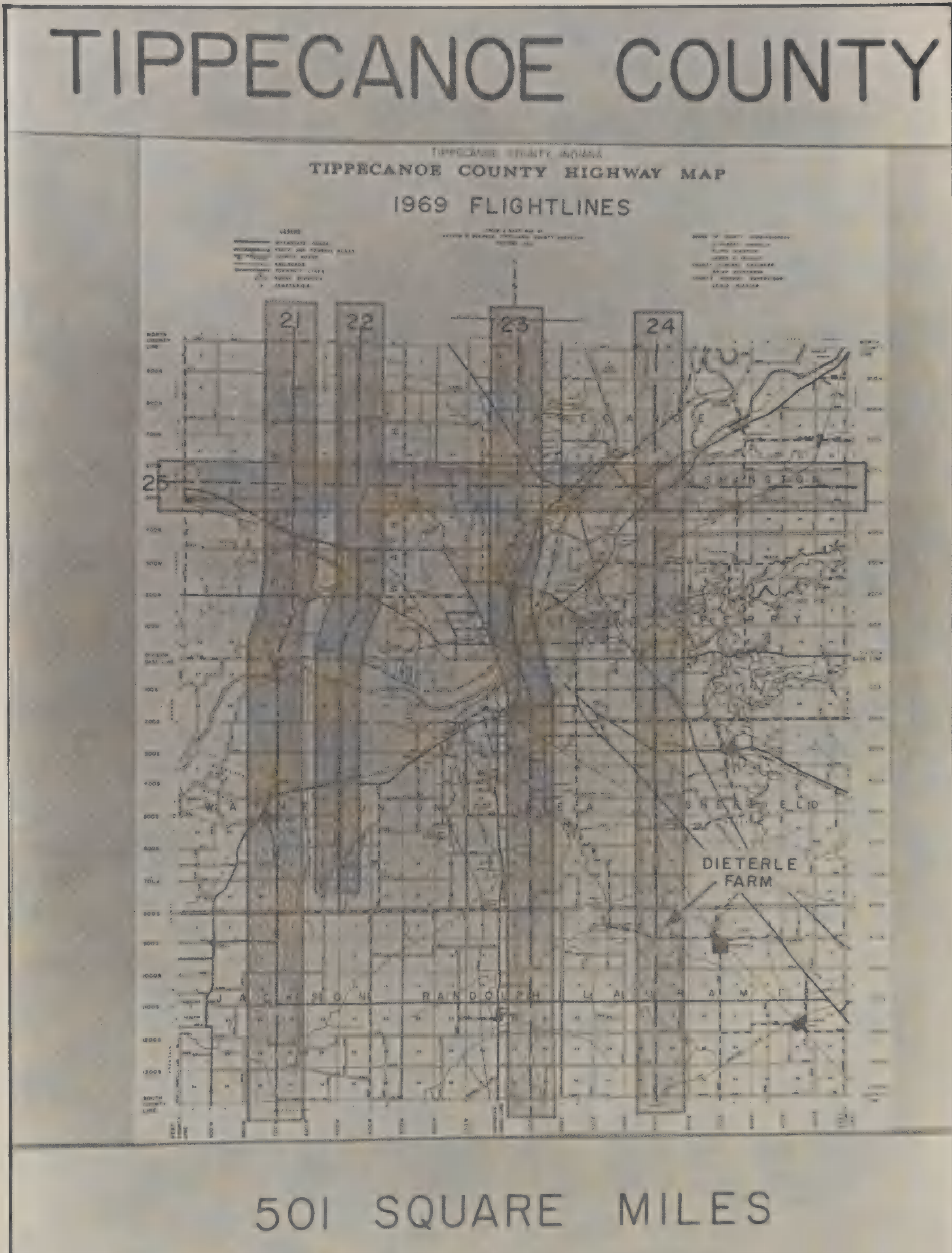



Figure 24. LARS flightlines over Tippecanoe County, Indiana.

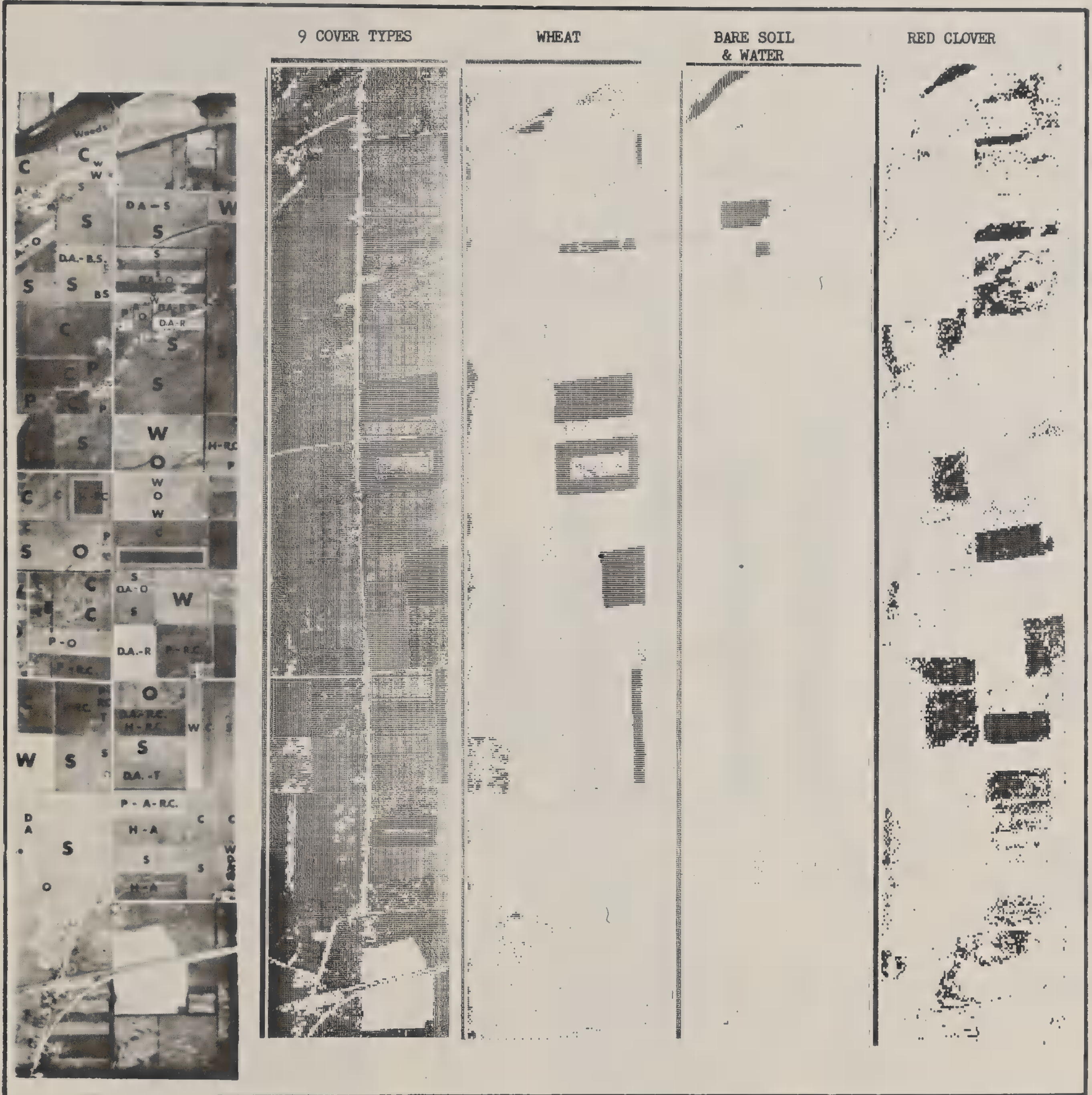



Figure 25. Photograph labeled with symbols denoting ground truth information and computer printouts of 9 cover types, wheat, bare soil and water and red clover.

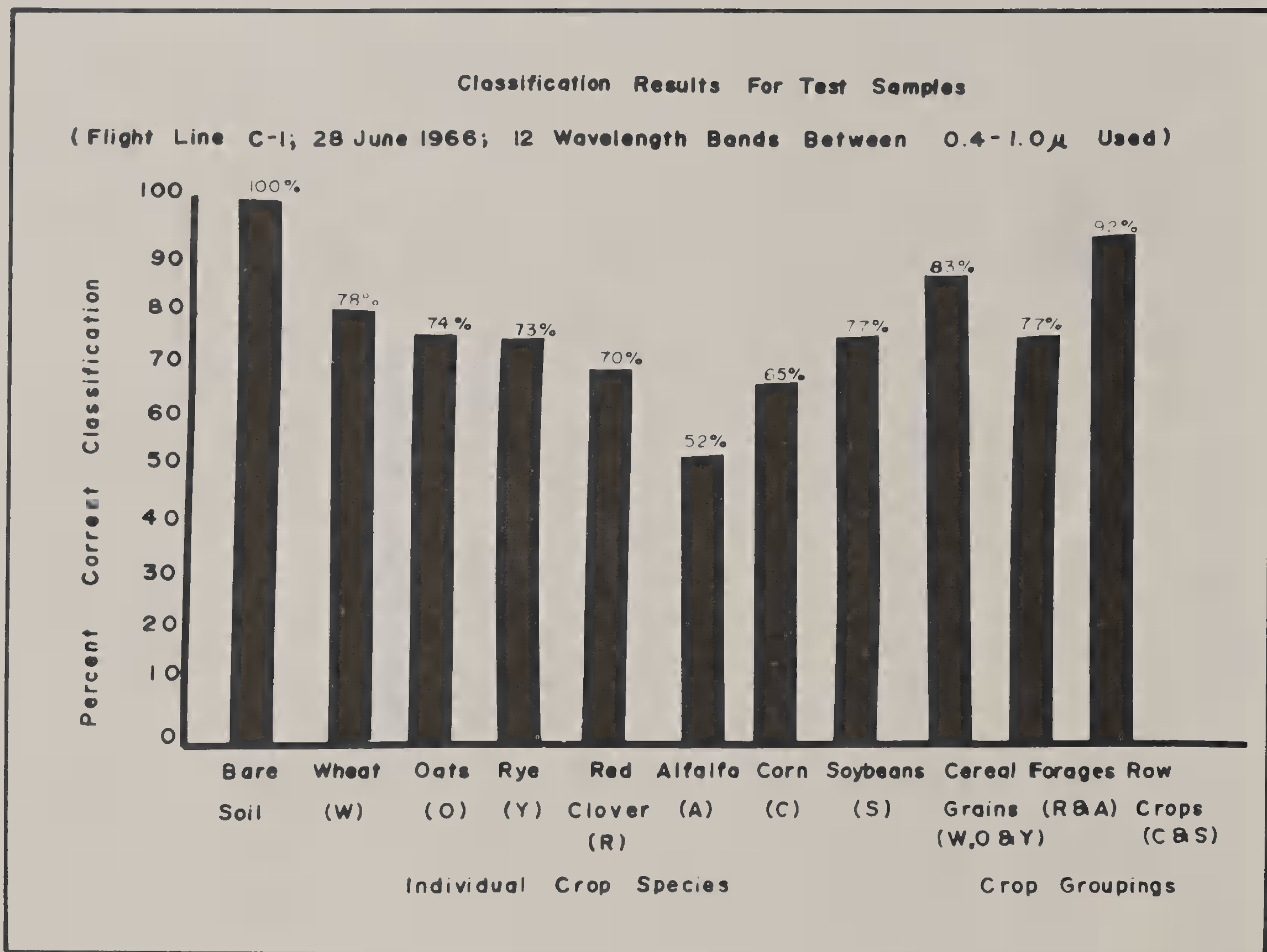



Figure 26. Classification accuracies for analysis shown in Figure 26.


Figure 27. Photograph and computer printouts of row crops and cereal grain categories.


TREES

Figure 28. Photograph and computer printout of the deciduous trees.

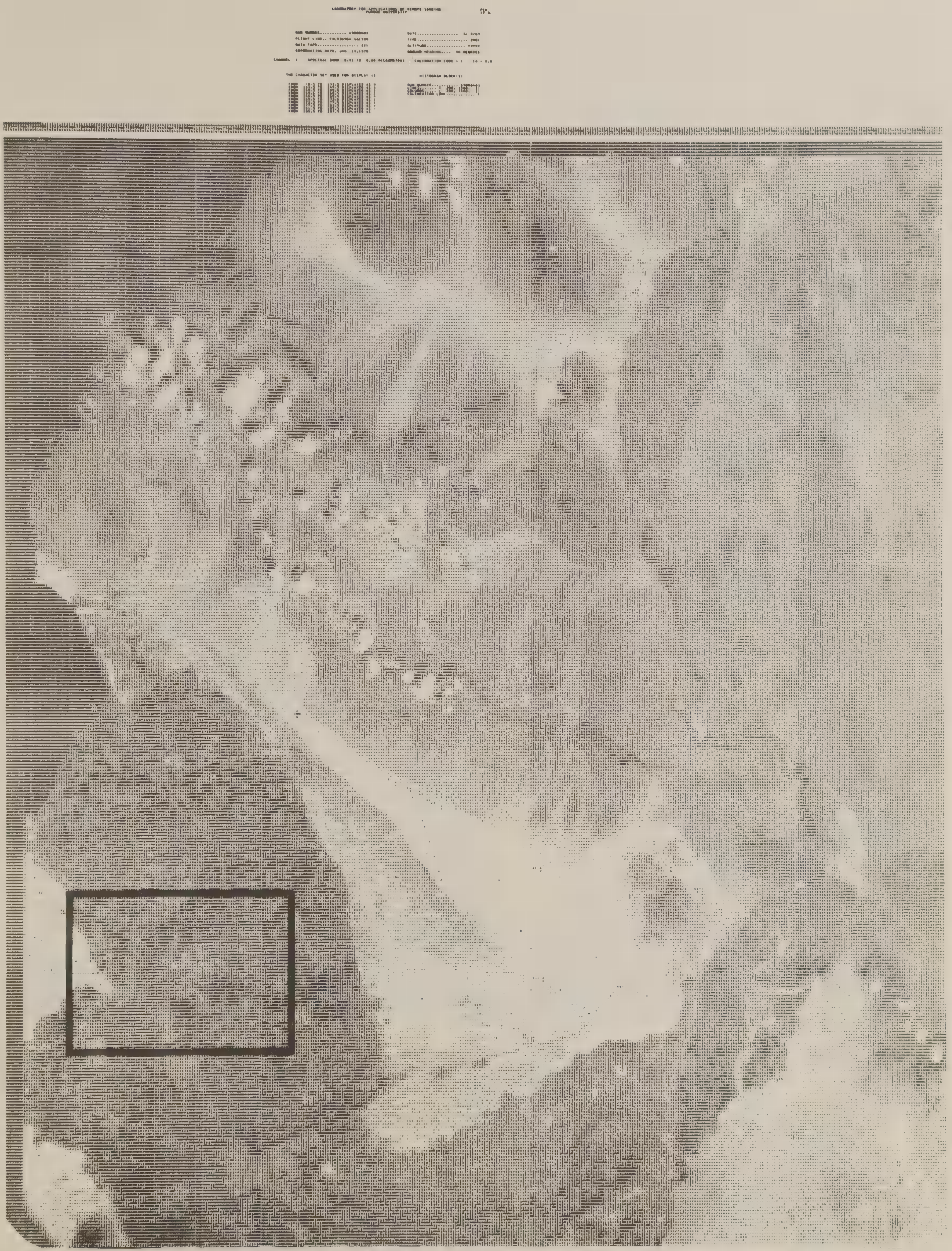


Figure 29. A 10 level computer printout of the Salton Sea area.

Figure 30. A smaller area from Figure 29 in a 1000 points per inch gray scale printout.

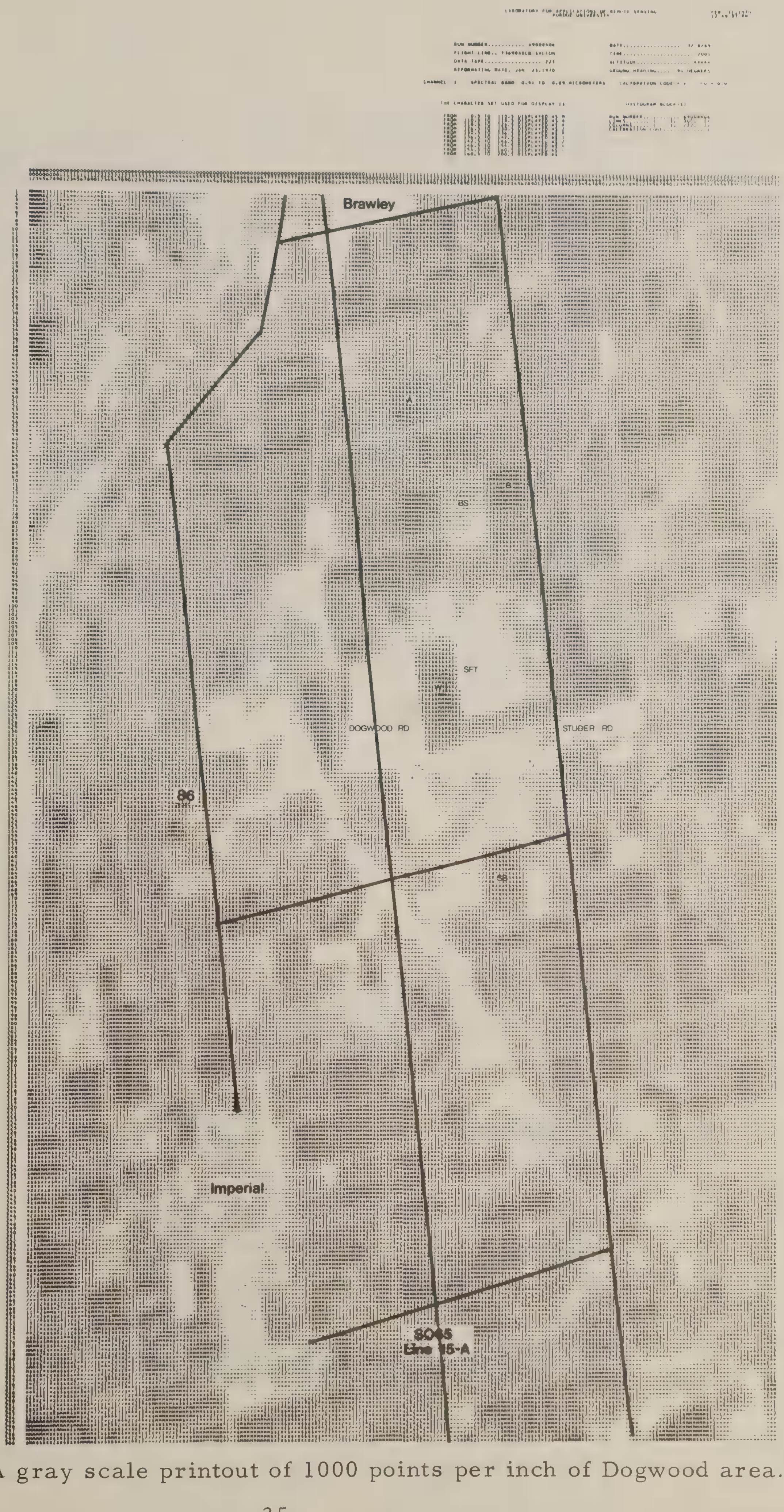



Figure 31. A gray scale printout of 1000 points per inch of Dogwood area.

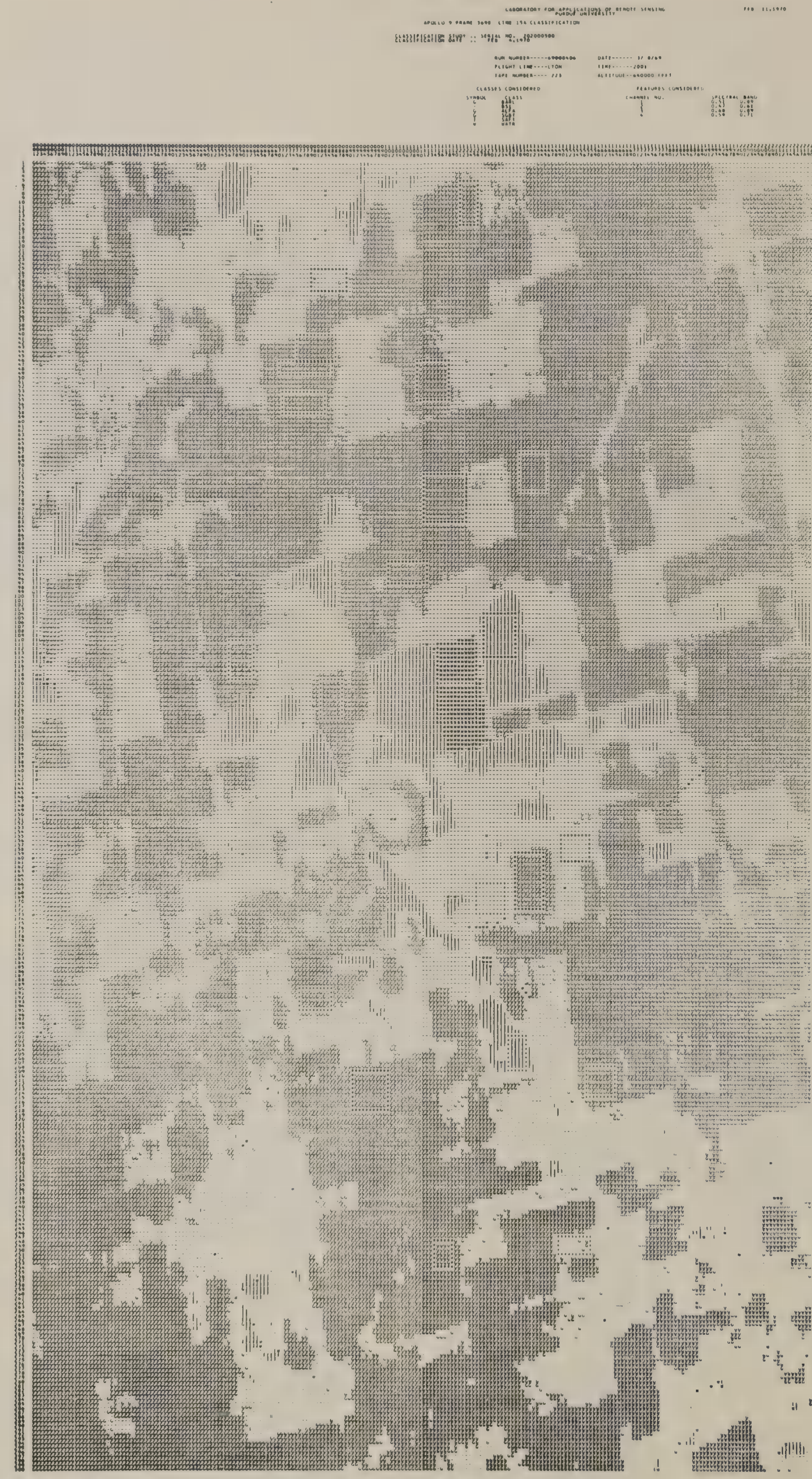



Figure 32. A classification of the Dogwood area into green vegetation (G), bare soil (-), saline soil (I) and water (W).

# CHALLENGE OF THE SEVENTIES

D. E. Ketcham [1]

Dave Ketcham, Director of Forest Pest Control, Washington, D. C. discusses the "Challenges of the Seventies".

Russ, ladies, gentlemen, it is a real pleasure for me to be here with you this morning at your Fifth Forest Insect and Disease Work Conference. Since I had the pleasure of attending the first one back in 1962, I don't really feel like too much of a stranger, in spite of all the new faces I see as I look around the room. I have been looking forward to coming to this meeting since Russ first mentioned it back in September or October. At that time I was just beginning a new job, and the thought that was upper-most in my mind was, "Where do we go from here?" This thought was what prompted me to suggest the what-I-thought-then-to-be-unique title, "Challenge of the Seventies", for my talk today. Although it is not so unique as I had at first thought, it is still very appropriate.

We are today on the threshold of a new decade. But before we look to the future, let's look briefly at the past. In 1961, almost 10 years ago, the Division of Forest Pest Control received the responsibility for the detection and evaluation of forest insects and diseases from the Forest

1/ Director, Division of Forest Pest Control, Forest Service, Washington, D. C.

Experiment Stations. This was the birth of the Division as we know it today. As I understand it, the basic reasons for this shift of responsibilities were to allow the researchers to concentrate more fully on research and to consolidate the action phases of the forest insect and disease control job into one unit. When the Branch of Forest Insect and Disease Control began its operation in July 1961, Russ had about 10 people to do the job. Today, this Branch is a Division, and Russ has 34 people. This was at last count. In those early years we spent many hours sketch-mapping insect and disease damage; today, you use aerial photography and sophisticated sampling systems. Where we used to spend long hours whittling down bark samples to make brood counts for southern pine beetle, you now use X-rays. If I am remembering correctly, in 1961 only four states in what is now the Southeastern Area had forest insect and disease control organizations which employed forest entomologists or pathologists. These were Virginia, Florida, Alabama and Texas. Today, 11 states have on-going forest insect and disease control programs.

Forest insect and disease control in the South has made giant strides in the past 10 years. But times are changing, and we must change with them. We are no longer working in a world where we can go along our merry way and concern ourselves only with the scientific and technological aspects of forest insect and disease control. Whether we like it or not, what we do now can hit the headlines. People are concerned. People are concerned about the environment. They are concerned about the effects of pesticides on their environment. They should also be concerned about the effects of pests, insects and diseases, on their environment.

My main point here, gentlemen, is that for perhaps the first time in many of our lives we have the opportunity to play a major role in a key National issue. We can either be the leaders, or we can be the goats. I hope that we will be the former.

So how do we play this leadership role? I would say that this is our number one challenge for the Seventies. One way to do this is to let the people know the impact which forest insects and diseases have on the environment. How can we do this, you ask, when we don't know ourselves? The answer to this one is simple; we find out. The determination of the impact of forest insects and diseases on our forest resources should be our number-one job for the Seventies. We must know how to measure impact if we are going to provide land managers with the information they need to decide for or against suppression. We must know how to measure impact if we are going to be able to determine the effectiveness of our suppression projects. And, perhaps most important of

all, we must have this information on impact to guide our forest insect and disease control program and to support our requests for funds. The Southern Forest Resource Analysis Committee also recognizes the need for this kind of information. In their report, the South's Third Forest, they recommend that the economic levels of insect and disease control be determined by correlating detection and control cost with losses.

Another of our challenges for the Seventies is determining where we go from here with pesticides. Many bills designed to regulate or prohibit the use of DDT and other pesticides and to authorize the study of their effect on the environment are pending before the U. S. Congress today. State Legislatures throughout the country are considering similar legislation. Arizona has banned the use of DDT and related pesticides for one year while researchers attempt to learn their effects. California banned the use of DDT and related pesticides in homes and gardens as well as the use of DDT in dust form for agricultural use. This bill expressed the intent that persistent pesticides will be totally eliminated from use at the earliest feasible time. Legislation passed by the Florida Legislature created a restricted pesticides category to be established by the Commissioner of Agriculture. Permits would be required to purchase, use, or possess a restricted pesticide. Maryland has just passed a bill prohibiting the use of DDT and several other chlorinated hydrocarbons in all cases except those where they are needed for the prevention or control of human disease and other essential uses for which no alternative pest control means are available. Other states have passed similar legislation.

The use of pesticides is also receiving attention at the highest level of the executive branch of Government. The review of the pesticide problem and its effect on the environment is a special charge of the President's Environmental Quality Council.

On November 20, 1969, the Environmental Quality Council reviewed and discussed the recommendations of the Commission on Pesticides which recently reported to Health, Education, and Welfare Secretary Finch. This report stressed that our society has gained tremendous benefits from the use of pesticides to prevent disease and to increase the production of foods and fibers. However, it underscored the continuing need to be informed and concerned about the unintentional effects of pesticides on various life forms in the environment and on human health. The report also contained recommendations to restrict the use of DDT and certain other "hazard pesticides" based on an evaluation of their hazards to human health, availability of an efficacious alternative, movement in the natural environment, concentration in the food chain, and other environmental considerations.

To carry out the intent of the recommendations of the Commission and to identify other appropriate actions that the Federal Government might take, the Council established a Committee on Pesticides under the Environmental Quality Council. This Committee will be chaired by the Secretary of Agriculture and will include the Secretaries of HEW and the Interior and the Executive Secretary of the Environmental Quality Council, Dr. DuBridge. The Departments of Defense, Transportation, and State, including the Agency for International Development, will also be represented.

The Committee on Pesticides has established a Working Group to provide day-to-day coordination and to develop program and policy proposals for consideration by the Parent Committee. This latter group has replaced the Federal Committee on Pest Control. The Program Review Panel of this Working Group met for the first time last Friday.

In Secretary's Memorandum No. 1666, Secretary Hardin established the policy for the Department of Agriculture of practicing and encouraging the use of those means of effective pest control which provide the least potential hazard to man, his animals, wildlife, and the other components of the natural environment. This policy states--

--where chemicals are required for pest control, patterns of use, methods of application, formulations which will most effectively limit the impact of the chemicals to the target organisms shall be used and recommended.

--persistent pesticides will not be used in Department pest control programs when an effective, non-residual method of control is available. When persistent pesticides are necessary to combat pests, they will be used in minimal, effective amounts; applied precisely to the infested area; and at minimal, effective frequencies.

--non-chemical methods of pest control, biological or cultural, will be used and recommended whenever such methods are available for the effective control of target pests. Integrated control systems utilizing both chemical and non-chemical techniques will be used and recommended in the interest of maximum effectiveness and safety.

What all of this means is that we can no longer sit back and depend on chemicals like DDT and BHC to do our job for us. We're going to have to take a long, hard look at all of our projects and programs involving the use of pesticides to see whether or not chemicals must be used to do the job. If chemicals are necessary, then we must be sure that we have identified all the possible adverse effects which might occur from

their use and taken the necessary steps to minimize them.

We must also intensify our research and developmental efforts to find effective substitutes for our persistent pesticides. I am confident that Dr. McLintock will cover this item in more depth under his topic, What's New in Research.

Gentlemen, as you can see from the challenges I have discussed so far, we need more than technology and expertise in forest entomology and pathology to do our job of forest insect and disease control today. Our activities involve people and have social and political as well as technological aspects. Our ivory tower has turned into a glass house. The public, and especially the youth of our Nation, are greatly concerned with everything that we do. Dealing with the public and involving them constructively in the protection of our forest resources from forest insects and diseases is perhaps our greatest challenge. One way to find out how to involve the public is to involve the public. The Forest Service did just this recently when they asked certain key figures to comment on a task force report on public involvement.

William E. Towell, American Forestry Association, said, "The thing that I would stress is that public involvement must be achieved before a decision is reached. Too often it has been merely a defensive tool after sides have already been chosen and opinions formed. More power to you in the Forest Service in this new effort."

J. Whitney Floyd, Utah State University, said, "I believe that these techniques of public involvement must generally be utilized. I think that the multiple use nature of the responsibility of the Forest Service places them in a position where they must endeavor, at all times, to get the fullest degree of public involvement obtainable. Because the more public involvement you get, the more understanding you should obtain. Consequently, you should get better cooperation, better support, and as a result, better judgement. I believe, also, that the involvement, if handled judiciously will not, and does not, necessarily imply that you are dependent on public involvement for decisions but that you are dependent on society for advice, opinion, and support. I believe the administrator can utilize most of these techniques in this matter and, at the same time, help make the public feel that they are helping with the decisions."

Brock Evans, Northwest Representative of the Sierra Club, said, "...the proposed processes and techniques for involving public participation in Forest Service activities are commendable and certainly represent a welcome departure from past traditions. However, if I

may speak frankly (and I know you want me to), I sense that the Forest Service is still failing to come to grips with the real issue, that is: what is the proper role of the forester (or indeed of any professional) in a Democratic Society.

"Throughout both your letter and the attached paper dealing with involvement techniques, one gets the feeling that professional expertise, rather than Democracy will prevail in determining goals and objectives. Rather than actually trying to inform and educate the public so that it may make a decision; the effort made, perhaps unintentionally, appears to be in the unfortunate position of really only paying lip service to public participation in order to get the support for professionally predetermined ends. I deeply hope that I am misinterpreting what I read."

Art Roberts, Western Forestry and Conservation Association, expressed interest in the analysis and support of the approach so long as the public involvement processes do not replace the long established pipeline of communication with the National Forest user groups and old established organizations.

Thomas B. Borden, State Forester, Colorado, said, "This looks like a good approach. I concur that the views of others, including State Foresters, should be solicited and considered when major programs and policies are being developed. In some instances it might be wise for the Forest Service to evaluate some past decisions and, if necessary, reopen the case for public comment."

Interesting? You bet. This cross section of opinion gives us a good look of how others see our programs. Our challenge is to make public opinion and involvement a tool, not a barrier.

Gentlemen, we are in for some exciting times. The challenges are here, and they are substantial. I am fully confident that we can meet them.

# WHAT'S NEW IN RESEARCH

T. F. McLintock [1]


T. F. McLintock, Director Forest Protection Research, Washington, D. C. discusses, "What's New in Research", in forest protection.

Perhaps the most significant thing that is "new in research" is the new book of rules under which the game of pest control is to be played. The chaotic situation with respect to chemical pesticides has put research on notice that we must come up with some workable alternatives, and soon. We don't know yet what kinds of deadlines we will be facing but we are quite certain that they will be too close. It isn't that we haven't been working on alternatives. We have, but the amount of effort has not been enough.

Insect diseases show probably the most promise for an alternative to DDT for control of some defoliators. Nuclear polyhedral viruses, which have the advantage of being lethal only to insects, have been successfully tested experimentally against the Douglas-fir tussock moth, European pine sawfly, Virginia pine sawfly, gypsy moth, and forest tent caterpillar. Work on the tussock moth virus has advanced to the point where it is ready for a pilot control study as soon as a suitable infested area can be found. Even with a successful test, however, registration of the virus will have to be delayed until clearance is obtained

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1/ Director, Division of Forest Insect and Disease Research, Forest Service, U. S. Department of Agriculture, Washington, D. C.

from the Food and Drug Administration.

This may or may not be a prolonged delay. What is needed is approval by FDA of a set of specifications for test procedures to establish the safety of an insecticidal virus preparation. If these specifications are confined to tests against rodents, the necessary evaluations can probably be made rather quickly. On the other hand, if FDA should also require human exposure to the virus, release for registration could take a great deal longer.

One major step forward toward operational use of polyhedral-type insect viruses has been the perfection by research of a technique for producing purified and highly concentrated virus preparations. The refined material, practically free of all contaminants, can be produced in sufficient quantities for control operations, and its availability should greatly enhance the probability of approval for its use by FDA.

Although the use of an insect's natural enemies has distinct possibilities for certain groups of insects, it is not by any means the only alternative to insecticidal control. Another approach is through the naturally-occurring chemical compounds in the host tree and in the insects themselves. Research in recent years has shown that such compounds have a number of quite different modes of action--i. e., as attractants, arrestants, repellents, and deterrents--each of which plays a specific role in determining attack patterns, reproduction, and survival.

Probably the best known work to date is that done on several of the Dendroctonus bark beetles, which has resulted in identification of specific chemical compounds which provide the stimulus for aggregation of the adult beetles. In California, cooperative efforts by the Forest Service, University of California, and the Stanford Research Institute have led to a field procedure for delivering and for evaluating the effectiveness of attractant compounds affecting the western pine beetle. Use of these compounds in a preliminary field trapping test in 1969 proved quite successful, and a larger scale study is planned for 1970-71.

In a somewhat different approach, two compounds isolated from the bark of elm twigs have been found to stimulate feeding by the elm bark beetle, carrier of the Dutch elm disease. The next step will be to find compounds which will mask or block reception of the feeding stimulus by the bark beetle and thereby prevent feeding. At the Research Triangle, both stimulants and inhibitors to the feeding of Pales weevil on loblolly pine have been isolated and identified. This should lead to a harmless dip treatment for pine seedlings which will prevent weevil attack without the toxic disadvantages of aldrin and other "hard" insecticides.

The concept of integrated control of forest insects envisions other possibilities--parasites, predators, chemo-sterilants, genetic resistance, and silvicultural control--which have varying degrees of promise for different insect problems. This is certainly the direction in which research is headed and must of necessity be the ultimate answer for insect control.

Do chemical insecticides have a role in such programs? The answer must be a strong affirmative _if_ the chemicals used are more selective, shorter-lived, and non-toxic to birds, fish and mammals; and _if_--in terms of aerial application--we can learn to confine them to the target area and eliminate the problem of drift.

Research does have something new to say about these two "if's". Our insecticide evaluation unit at Berkeley has for some time been trying to stabilize pyrethrin, a naturally occurring compound found in plants and which is non-toxic to warm blooded animals. By means of some complex chemical manipulations in the laboratory, our scientists have succeeded in extending the life of this insecticide from 10 minutes, or less, to 4 hours, or more, without impairment of its efficacy. This spring we will undertake, cooperatively with Pest Control, a field experiment to learn more of the behavior of this material when it is exposed to sunlight and natural atmospheric conditions.

We are also establishing a new research unit to study methods of aerial application of insecticides. This group, to be located at Corvallis, Oregon, will work closely with Forest Pest Control and the Missoula Equipment Development Center. It has been set up primarily to perfect application techniques for microbial insecticides. Although research on the efficacy of insect viruses and _Bacillus thuringiensis_, a bacterial insecticide, are well along we are not sure how these materials can best be formulated for aerial dispersal, or how their effectiveness may be altered by such treatment.

But this aerial applications research unit will also be looking at the complex of conditions and forces which influence the dispersal of any liquid material after it is released from a spray boom. For example, research has shown quite conclusively that it is the very small insecticide droplets (less than 50 microns) that are most efficient in killing the spruce budworm. But then we found that we didn't know what kind of a droplet spectrum is required at the spray boom to yield 50-micron droplets on the foliage 200 feet below.

Although the need to develop effective alternatives to chemical control is very great, the hard fact is that we are not getting the job done; our

rate of progress is too slow. "What's new in research" is that we are now completely overhauling our priorities, not only to better identify the most important economic problems, but also to determine which ones research has the greatest likelihood of solving in a reasonable length of time. The next step will be to develop realistic estimates of the manpower and dollars required to solve the major problems--or at least to make substantial and measurable progress toward their solution--within specified time limitations. Then will come some tough soul-searching, and very probably some rather ruthless decisions, for reprogramming our available resources to achieve the goals we've set for ourselves.

It was suggested recently, following a particularly emotional plea for action to save the American elm, that a case could probably be made for assigning virtually all of our Forest Insect Research personnel and budget to solving the bark beetle vector problem of Dutch elm disease, which we could probably do in 3 years. The point was further made that if successful, it might be regarded as one of the greatest contributions ever made to the improvement of environmental quality. Although the specifics of this premise are debatable, the principle involved is unquestionably valid. A judgment must be made as to how much effort we can afford to put on relatively--mind you, I say relatively--unimportant pests such as the balsam woolly aphid, the Nantucket pine tip moth, brown spot, or heart rots, when we still do not know how to contain the southern pine beetle, or control fusiform rust.

It is quite obvious that we in Research are going to have to listen carefully to Federal, State and industrial forest managers and pest control specialists before we can reach a wise judgment on what is and is not "relatively unimportant." We realize only too well that today's nuisance could become tomorrow's nemesis, and that more than once management has had to make important decisions with little or no research to back them up. Also, both management and Research must be aware of the possible consequences if we do focus more attention on Dendroctonus and Cronartium at the expense of lesser pests.

A related question which Research has skirmished with over the years, but has only recently faced up to, is when to terminate work on a problem. Any good researcher can always see intriguing unanswered questions ahead of him, but there is a point where any additional information may be primarily frosting on the cake, a luxury which we actually cannot afford.

As one example, we are now looking rather closely at our research on Fomes annosus to get a better feeling of just exactly where we are in

terms of control, and how much and what kind of additional research will really be needed. The outcome of the present extensive pilot control study--which incidentally, is an exceptionally fine example of cooperation between Research and Pest Control--will undoubtedly give us some key answers to this question. Here again, we in Research need to pay close attention to what the forest manager and the pest control specialist are saying in this regard. It might be worse to give up research on an important problem prematurely than to extend it beyond the point of diminishing returns.

All of these questions about priorities and pay-off which are so vital to effective research planning can rarely be answered to everyone's satisfaction. But they may not be answered to anyone's satisfaction unless another fundamental and complex problem of long standing is at least partially solved. This is the great unknown of insect and disease impact. Here the familiar quotation about the weather is appropriate: "Everyone talks about it but nobody does anything about it".

The difficulties which you people, as working researchers and pest control specialists, encounter because of lack of knowledge of pest losses are compounded for those of us with long-range programs to plan, and short-range budget decisions to make. The figures which we must often use are those which appeared in the 1965 "Timber Trends" report and which were based on 1962 data. Not only are they now out of date, but in terms of completeness and accuracy, they were inadequate even when they were new. Although it provided rather gross estimates of total mortality, which were certainly better than anything we had previously, the report did not and could not come up with anything useful on growth impact. Except for scattered State or Regional studies, the situation remains the same today.

There is, however, some reason for optimism. Dave Ketcham and I have agreed that this is perhaps the number-one priority job which demands our attention. We must try to devise a scheme which will permit us to begin to accumulate meaningful information on all important pest-caused losses. We are already agreed on several basic requirements of such an endeavor: It must be a continuing effort; it must have joint collaboration by Research, and Pest Control; it should involve participation by Forest Survey; it must not only look at timber damage but also at injury to environmental values; and--because of the size, urgency and complexity of the job--once procedures are spelled out and responsibilities assigned, this work will probably have to take precedence over certain other jobs, with men and dollars reallocated to it as needed.

The design and implementation of a joint Research-Survey program to estimate annual losses in both mortality and growth resulting from specific insect and disease pests is a formidable enough task. But complicated as that is, the total impact appraisal job involves other considerations, the most important of which is probably an accurate plugging-in of resource values. I mentioned in passing the necessity to take into account damage to environmental quality resulting from insect and disease depredations. At the moment we are only sure about two things in this regard: First, we know that criteria for setting values will be very difficult to establish; and second, we know that at least under some circumstances they can far surpass stumpage values.

The situation on the San Bernadino National Forest in southern California is a case in point. There we have been studying impacts of Los Angeles smog on ponderosa and Jeffrey pine, and have recently determined--using, incidentally, a newly developed remote sensing technique--that more than 100,000 acres now have moderate to heavy smog damage. Most of the National Forest and adjoining areas are valuable primarily for recreation--hiking, camping, picnicking, water sports--and there are hundreds of individual homes, from vacation cottages to $150,000 mansions. Enjoyment of all these uses and values depends to a large degree upon the presence of majestic stands of ponderosa and Jeffrey pine. When these trees are killed--and well over a million of them are dead, dying or severely injured--how do you appraise the impact in meaningful economic or social terms?

Another quite different kind of impact is created when epidemics of defoliators such as the elm spanworm or the gypsy moth take over campgrounds and picnic sites. Very few economic analyses have been made of the effects of such an event on the tourist business of adjoining communities, but it is bound to be substantial during periods when billions of caterpillars are dropping from trees on to anything or anyone that happens to be underneath.

But even the impact on the timber resource itself has to be looked at, particularly in the South, in a different light. If the expected future demands for timber in the South are to be met, production will have to be accelerated sharply. It seems likely that the greatest increases in yield will come from intensive management on a relatively small percentage of the total commercial forest land. And it is here that pest problems may become most acute, but where impact may be most difficult to predict with any degree of reliability.

Intensive management means site preparation, genetically improved stock, brush control, thinning, fertilization, and perhaps some form of

soil moisture control. Such treatments create and maintain new environmental conditions and different growth patterns which could prove to be much more favorable for insects and disease than the natural ecology. Furthermore, with the substantial investments required for intensive management, the threshold of tolerance for any damage which lowers yield or lengthens rotations is very appreciably reduced.

Another factor which requires consideration is the probable future of hardwood culture. The increasing use of hardwoods for pulp, the necessity for fuller utilization of lands which are primarily suitable for hardwoods, and the recent research advances in intensive hardwood culture all suggest that species like cottonwood, sweet gum, sycamore, and yellow poplar may soon rank with slash and loblolly pine in economic importance, and demand equal attention from both insect and disease research and pest control. Here research may have a lot of catching up to do in a very short time. Historically, insect and disease research in the South has concentrated on softwoods, and with good reason. Relatively little is known about the pest problems likely to afflict key hardwood species, particularly when they are grown under intensive management.

"What's new in research" here is the realization that pest control must be an integral part of management, and that research on pest control must be closely tied to research on intensive culture. It is now Forest Service policy to define research problems, whenever appropriate, in terms of what we call their multifunctional aspects, and our research programs in the future will be designed, planned, and conducted accordingly. This simply means that wherever a problem requires a joint interdisciplinary attack by silviculturists, geneticists, entomologists, pathologists, soil scientists, or whatever, such a scientific team will be brought to bear upon it.

Finally, "what's new in research" is an exciting array of new insights and concepts about the mode of action of diseases and the behavior of insects, and their relationships to trees. You will hear much in the next few years about stress in plants: Environmental factors that cause it, physiological and biochemical processes that are affected by it, its relationship to insect and disease attack, and how it may be detected--particularly through the use of remotely based sensors. We are beginning to get some glimmerings about the fundamental mechanisms of disease resistance, and we may see the day when the degree of immunity to fusiform rust can be quickly determined in a seedling by chemical analysis. We are only beginning to understand the effects on trees of long term exposure to very low concentrations of chemical air pollutants. Entomologists and pathologists are finally getting together to study the

possible interlocking relationships of insects and diseases. The role of mycorrhizae in protecting roots from soil-borne diseases by the production of antibiotic materials is being uncovered for the first time. We can now look forward to the day when we will know why and how a bark beetle can successfully attack a pine but not an oak, and exploit this knowledge in its control. Techniques of germ-free plant culture recently developed by one of our pathologists, working in cooperation with NASA at the Lunar Receiving Laboratory at Houston, may revolutionize the study of insect and disease impact.

The look ahead for research is bright: The problems are challenging, the opportunities for really significant advances are exciting. By the time the Sixth Forest Insect and Disease Work Conference rolls around much--perhaps most--of what I have talked about will have been accomplished, and one reading this paper then will probably lay it aside with a yawn, and ask: "So what else is new?"

## INDUSTRIAL NEEDS IN PEST CONTROL

Norman E. Johnson [1/]

N. E. Johnson, Director of Research for Weyerhaeuser Company, New Bern, North Carolina discusses "Industrial Needs in Pest Control".

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Very often one finds he should have heeded earlier inclinations about accepting a particular assignment. I know I should have now. The saying that fools rush in where angels fear to tread was never more appropriate. There is abundant evidence to support this. 1) I'm so new in the South I haven't developed a taste for collards or grits, 2) Weyerhaeuser Company is so new in the South that the name Weyerhaeuser is misspelled and the title of the Company misstated on the program, 3) there are at least two men in the audience, Barry Malac of Union Camp Corporation and Charles Driver formerly of IP that have a better grasp of the pest control needs in the South and 4) much of what I've got to say has been said by at least three preceding speakers. In a way this is good, we're on the same track--let's hope it's the right one. Those of you who had too much lunch and are not going to keep awake, give me your attention long enough to say that if you take what Directors Craig, Ketcham and McLintock said this morning and apply these things to verifying and supporting the last statement you see on the banner above me, (Forest Protection Doesn't Cost, It Pays) you have the elements of my talk. I did not read their speeches, but much of what I have to say came from pleas I and other industrial protectionists have been making for years. It would be flattering to me to assume they've read the speeches I've made in the past. But I rather expect that we would all come to similar conclusions of what's needed once economic restraints are thrust upon us. With these preliminary comments let me "rush in".

If I didn't believe that some improvements could be made in the way forest insect and disease problems are being dealt with I wouldn't have accepted this assignment. However, I don't want to sound too critical because I know of the tremendous difficulty attendant with the "solving" of many biological problems. It has been comparatively easier for us to get to the moon than it has been to discover the cause and cure of cancer or to find out how the salmon gets back to where it hatched. Answers to some of our forest problems, e. g. rootrots and the balsam wooly aphid seem to be as hard to attain as those surrounding the cancer problem. Realizing then, that some of our forest pest problems seem to defy any solution, let alone economical ones, I still think there are some areas that need attention before we can fully satisfy industry's pest control needs.

## DAMAGE ASSESSMENT:

First of all we have not been able to adequately assess the damage that insects or diseases are causing. Seldom have forest protectionists assessed insect or disease-caused damage in a dynamic way. Too often we list trees killed or acres infested, neglecting the growth that is likely

to take place on the remaining trees in the stand after damage but before harvest. When we look at damage at any one point in time we tend to overexaggerate that being caused by certain organisms. On the other hand by not looking at the forest as a dynamic system, we may be grossly underestimating damage caused by other pests, especially those insidious ones that cause damage over a prolonged period. If the effects of particular organisms on a stand are indistinguishable at harvest, no matter how apparently severe at any time before harvest, then no economic loss has occurred.

Some entomologists I know feel that the job of assessing losses caused by insects belongs solely to the forester. However, I feel that the economic entomologist needs to know nearly as much about the dynamics of forest growth as he does about the insect. I believe it is the duty of the protectionist to point out a suspected relationship between a particular insect or disease and tree growth or mortality and then to work with the inventory forester to assess the real impact of the organism on growth of the affected stand. I've found that foresters are generally too busy with everyday crises to assume the full responsibility of assessing the damage being caused by pests. But they are usually willing to work with a protectionist to add the "real life" touch that is needed for meaningful assessment of damage.

## SETTING OF PRIORITIES:

Because we have not been able to assess in a dynamic and realistic way the role that insects and diseases play in affecting profits from our forests, we are not able to set realistic priorities--the second area I think needs improvement. Sometimes I feel we have spent a disproportionate amount of effort on bark beetle research and control. Other insects have received less attention sometimes just because they were not as interesting to the researcher as bark beetles. True, bark beetles kill a lot of trees, but even the earliest entomologists were able to suggest essentially the same prophylactic measures we use today. Bark beetle incidence is most often associated with catastrophies such as hurricanes, drought, fire, or with diseased trees over which we have little control. To be fair I must say that because of the high priority of bark beetle research, some new and interesting ideas of bark beetle control are ready for field trials. We'd all like to think that they will allow us to regulate bark beetle populations.

Rather than rank insect or disease problems in descending order of the amount of trees they kill, we should also consider the probability that something can be accomplished on a problem in a reasonable time. For example, in the old forests of the West, heartrots cause the greatest

loss of wood, but unlimited amounts of research would do little to change the situation. On the other hand, diseases affecting nursery seedlings cause little economic loss compared to other forest diseases, yet their control would seem a lot easier to bring about than that of heartrots and therefore easier to justify.

When we talk about the setting of priorities, perhaps we need to be more specific. Maybe we don't set the Nantucket tip moth as one priority and *Fomes annosus* as another. But, rather we might put as high priority the determination of damage caused by tip moths, but their control would be placed in low priority until the amount of damage they cause can be determined and agreed on.

We should look at long term trends in forestry before completing our priorities. Both entomologists and pathologists have been slow to sense changes in the character of the forest. This may be more so in the West than the East. In the West it has been hard for some protectionists to let go of their favorite pest even though it is destined to disappear with the old growth. But even in the Southeast, the nature of the forest is continually changing. The rotation age is creeping steadily downward and we will soon be on a plantation economy. On many areas we are changing the very nature of the site by drainage, bedding and fertilizing. Our newer plantations are composed of trees chosen for superior growth qualities. Some of these selected trees have shown less susceptibility to insects and diseases and others more susceptibility. With an even-aged monoculture, composed of trees of limited genetic variability and treated in a number of unnatural ways, can't we guess that at least the degree of damage caused by various pests, if not the pests themselves, will differ in the future from what we see now? One could predict increased incidence of certain kinds of pests in areas where trees are being damaged by air pollution.

## SENSITIVE SURVEYS:

At least part of our protection effort should be directed towards monitoring the dynamics of pest populations in these man-made and man-influenced forests. But, do we have the survey and appraisal system to monitor these new forests? Not really. Our surveys, even those using modern remote sensing techniques, are mostly geared to detect damage after the fact. We do not have the manpower nor the techniques to assess pest population trends per se.

The Canadian insect survey system is a step in the right direction. Ecologists are finding this survey to be a gold mine of data for their computers. From this kind of information we can start to relate pest

population changes to environmental variables. Of course, we all see the need in this. Without predictive information on pest population trends we must always react to a crisis. We cannot plan ahead. Whereas we may never be able to predict climatic changes, we might be able to predict the consequence of a particular climatic change on some insect or disease. Contrary to what it seems, an insect does not increase from very low to very high numbers in one generation. It usually requires at least 4-5 generations for an epidemic to occur even under the most favorable conditions. With close monitoring of population trends, we would have more time to plan control programs. To be able to attack an insect population while it is on the upswing can mean a substantial saving. On most of the defoliator outbreaks that I've been involved with on both the West coast and in the Northeast, we applied control the year that the population reached its peak and a year or so after measurable damage had occurred. A survey system sensitive to the insect itself rather than to the damage it caused would have permitted us to suppress the insect sooner and nearly eliminate tree killing. We need this advance information more now than ever because of the increased complexity of a control program. With the widespread concern over contamination of the environment, it takes longer to get clearance to use chemicals and as a result control programs are sometimes delayed even longer. The "around-the-corner" feasibility of viral or bacterial control demands for its success close insect population surveillance. These diseases will not kill as fast as traditional insecticides.

CONTROL:

This leads me into comments about insect control. I feel that a disproportionately small amount of money and effort is being directed towards more traditional kinds of control including both chemical and silvicultural. Research directed towards control with insecticides is currently held in low esteem by many university and governmental researchers. None of us want to unnecessarily poison the environment, but we should not "run scared". There will continue to be uses for insecticides and we need competent researchers to find out which ones we should use. I don't belittle control efforts using juvenile hormones, phenomones, sterilants, viruses, bacteria or parasites. It is the imbalance that worries me. I'm particularly concerned about substitute materials for Pales weevil control now that DDT has come under such intensive restrictions. Industry would consider it a noble effort on the part of the researcher finding this substitute. I also feel that regardless of the techniques we have for battling the pest itself, for long term control we must manage our forests in a way that will achieve minimum losses with a minimum of short term protection measures, thus we need more studies of ways we can plan, manage and manipulate our forests in order to keep pest-

caused losses at a minimum. Ecologists are becoming famous for talking about what silviculturists have been talking about for years. In truth, there have been very few good silvicultural studies mainly because of the immense effort required. I feel we need some major regional studies of what we can do to reduce the incidence of insects and disease in our forests.

The genetics program in the South has shown that natural resistance is a fact and the geneticists weren't even looking for it. We now know that some clones are nearly resistant to fusiform rust, while others are extremely susceptible. Some clones are more susceptible to Dioryctria attack than others. It is intriguing to contemplate what we could achieve by selecting for insects or disease resistance. However, I know the burden that multiple selection can lead to. I'm delighted to see that this topic will be discussed later on.

I've said we need to improve on our:

-- assessment of the real role that insects and diseases play in a dynamic forest system,
-- setting of priorities taking into consideration
  (1) those insects causing the greatest damage now,
  (2) the probability of arriving at a solution to the problem in a reasonable time,
  (3) the changing nature of the forest and its pests,
-- detection system so that we can determine trends based on the pest population rather than the damage pests cause,
-- control studies using traditional insecticides, silvicultural treatments and natural tree resistance.

## INDUSTRY'S RESPONSIBILITIES:

Industry can't sit idly by and hope that all its protection problems will be taken care of for them. We must help in the assessment of damage and the setting of priorities. Once, through mutual effort, we establish the "real life" importance of certain pests we need to create an awareness of this importance among our personnel. This is not easily accomplished with men who are concerned with other problems and crises. Industry needs to be involved in surveys that will detect trends of forest pests on their own lands. Industry has the responsibility for taking the available information on damage being caused, trends of infestations and cost of control and actually analyzing the financial returns of control efforts in light of other alternative uses of this control money. Modern forest products companies have expanded their horizons so greatly

in recent years that they have a larger number of alternatives for their dollars. In the forest itself they may elect to spend more money for site preparation or fertilization of new plantations rather than treating for an insect or disease causing a known amount of damage. They may elect to let certain insects and diseases reduce stand stocking somewhat with the realization that better game habitat will result and that money is to be made through hunting leases. On the other hand, if we really know the facts about the damage caused by various pests and the probability and cost of controlling them, we may find that forest protection should be getting even more of the corporate dollar.

I've elaborated on the pest control areas that need strengthening. I've been intrigued for a long time on actual ways to accomplish better pest control research. Here, I'm mainly concerned with applied research because I don't feel that we can regiment basic research. With applied research a formal organization is sometimes warranted. For example, I doubt that the tree genetics program in the South would have progressed very far without the cooperative programs that were set up over a decade ago. The cooperative approach has worked with other projects too, namely fertilization, hardwood silviculture and volume-table development. Why not then a forest protection cooperative? This cooperative would consist of different protection researchers within the Federal and State governments as well as industry, Within the cooperative there would be sub-groups of common interest. Let's take an example. Suppose we want, and we do, to find within the next year or so, a good substitute insecticide for Pales weevil control. The sub-group within the cooperative would meet and draw up a plan of action for testing new materials. A working plan would be developed which could be used in all testing areas. In this way the same materials would be tested in a similar fashion in a number of different localities the same year. The results could then be analyzed on a central computing facility and within one year we would have results we'd have some faith in because of the large number of replications and because researchers were using the same techniques and measuring outcome in the same way. It might be that the number of chemicals to be tested would be too large for each researcher to test the whole lot. This could be handled by giving each researcher a portion of the insecticides but with one or two of the insecticides replicated in a fashion that would allow a check on techniques or unusual circumstances. The more promising materials could then be tested further again using a standard working plan. Within two years we should have the Pales weevil problem in pretty good shape and be ready to tackle another pest problem in a similar manner. Probably several problems could be handled concurrently.

To be most helpful to industry, forest protection research must become more problem-oriented. The researcher must be made to feel that solving a problem is as important or more important than adding publications to his bibliography. Research administrators need also to recognize and reward problem-oriented work in which his investigator may only be one of a long list of cooperators. One area of improvement that I perhaps should have listed as a major one deals with publication. We need to communicate significant findings to the men "on the ground" much more quickly and efficiently than we are now. Not only do we have a 1 - 3 year delay in publishing through regular journal channels, many of these journals are not generally available to the practicing forester. Then too, publication itself is a poor means of getting the information across. We may need to evaluate other techniques to spread the word. This is another involved topic so I'd better stop now.

I appreciate being asked to make this presentation. From what I see of the program, I'm sure to gain more than I give.

## SENSORY RECEPTION IN INSECTS

Philip S. Callahan [1/]


P. S. Callahan of the U.S. Department of Agriculture's Insect Attractants Behavior and Basic Biology Research Laboratory at Gainesville, Florida talks on "Sensory Reception in Insects".

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It is perhaps redundant to point out that size alone imposes certain restrictions on the functioning of the insect nervous system. The distance over which a nerve impulse must travel, when comparing an insect to a mammal, is short but at the same time size imposes a reduction on the number of neurons contained within the system. Reduction in numbers of neurons implies a reduction in the informational capacity of the system. In other words, insects, because of their size, have sacrificed informational capacity for speed of neural transmission. Insects, however, have complex arrays of dielectric sensillae on their antennae. The complex arrangement and the intriguing forms that various sensillae take are indicative of multiplicative or correlation arrays. The multiplicative array is a signal processing antennae in which the wave form is difficult to predict but which is capable of incoherent detection. Frequencies would be assumed to have the wavelength dimensions of the dielectric spines and to emanate from incoherent sources (e. g. from plants or other insects). Such an array would allow for long post-detection integration times, thus compensating for loss in predetection signals-to-noise ratio. It would be a particularly suitable array configuration for insects, as a certain amount of signal processing would be accomplished at the antennae itself, thus "making up", so to speak, the loss of informational capacity brought about by the reduction of neurons in the insect nervous system.

Dielectric waveguides, e. g. rods or tubes of dielectric material in free space, are considered as open waveguides and are by nature periodically spaced. They may be ring shaped, helical, corregated, tapered, or have walls with slits or partially transparent walls. Every known type may be found in some insect or other arthropod. Before examining the complex antennae systems of insects, let us look at the infrared portion of the spectrum since the frequencies that would be expected to match the dielectric sensillae are in this region.

## INFRARED RADIATION

Sir William Herschel, in 1800, discovered the invisible electromagnetic energy of wavelengths beyond the red part of the spectrum. We now know that all objects whose temperatures are above absolute zero emit infrared (IR) radiation. Over the years, the gap in our knowledge of the spectrum between IR radiation and microwave radio frequencies has been slowly narrowed. Glagolewa-Arkadiewa (1924) demonstrated IR radiation of about 90 $\mu$ by exciting small hertzian oscillations in the form of brass filings in oil. Nichols and Tear (1923), using a diffraction grating for the measurements, demonstrated hertzian (far infrared) waves of wavelengths down to 220 $\mu$.

The standard for IR definition is the blackbody, essentially any object that absorbs all received radiation. The intensity and wavelength of IR radiation depend on the absolute temperature in degrees Kelvin ($^{o}$K.) of the emitting object and on its surface finish. The radiation and absorbing efficiency of an object are called its emissivity ($\varepsilon$) factor (table 1) and is unity (1) for a blackbody. A mirror is a poor radiator and absorber of IR, having an emissivity factor near zero. A black rough surface, such as lamp black, is extremely efficient as a radiator and absorber and approaches unity. Objects with an $\varepsilon$ of less than unity are termed gray bodies. Most objects including the moth and the human body, fall into this category.

IR radiation is often wrongly termed heat radiation, because it generates heat in any absorbing object in its path. However, light rays, x-rays, and even high-intensity radar beams have the same property. Since the IR band falls between visible light and radio ($7.5 \times 10^{-4}$ mm. to 1 mm.), or in terms of microns $0.75\ \mu$ to $10^{3}\ \mu$, it is extremely intriguing and demonstrates many of the characteristics of both. It may be focused by lenses and yet can be transmitted like radar or radio through materials that block visible light. As I have often stated in postulating my theories about the IR environment of night-flying moths, we are dealing with a region where light acts like radio and radio like light. Emphasis is added to my comparison by the fact that present-day infrared technologists make use not only of optics--refraction and reflection techniques--but also of radio techniques--waveguide and resonant cavities--to detect such radiation.

IR radiation has definite characteristics that make it useful for detection purposes (Hackforth 1960). IR systems are lighter, smaller, and less complex than conventional radar systems, do not generate the detrimental side lobes of radar. One great advantage of an IR system is that it is passive and requires no transmitter to obtain the return signal. In other words, it senses the object directly. These advantages are pointed out for the obvious reason that where location is concerned, the efficiency is indisputable whether or not such a detection system were to be utilized by man to detect rockets or is a facet of nature itself in the marvelous intricacies of insect life.

There is no doubt that moths are attracted to electromagnetic radiation. We are all familiar with the moths' propensity for the ordinary 60– watt incandescent lamp. Figure 1 gives the energy curve for such a transmitter. It is my contention that we have as much right to insist that the moth is attracted by the much greater energy of the longer wave IR output (a) as we have to insist that it is attracted by the lesser energy of the shorter wavelengths in the small visible area of the luminosity curve (b).

It is well known that the higher temperatures produce shorter wavelengths (light and that $\lambda$ max. displaces toward the longer and longer wavelengths as power and heat are reduced (fig. 2). This displacement becomes obvious when we hook a 60-watt tungsten lamp to a rheostat and reduce power. The visible spectrum shifts from white to red heat and finally to black heat as the filament "goes out", no longer sensitizing our eye (fig. 2). Inability of our eye to detect black heat does not mean that such a self-emitting body is not incandescent.

As Barnes (1963) pointed out, such objects emit no visible light and thus must be illuminated by some external hotter source to be detected by the eye. However, to any instrument having IR detection capabilities, these objects would be highly incandescent. All objects in nature, regardless of their temperature, are IR incandescent. Animals and plants are constantly absorbing and emitting IR radiation. In short nature is inherently a thermal IR environment, and all objects in nature with high emissivity (table 1) are incandescent point sources of IR radiation.

## BIOLOGICAL DETECTORS

If we are to assume that insects, and in particular moths, can detect IR, then we must examine closely their anatomy to determine whether they have any organs that might be considered as having an IR detector configuration.

The most obvious areas of interest for study are the compound eyes and the ocelli, both of which have optical configurations. Modern microwave techniques, however, indicate that the antennae also display certain characteristics that should be subjected to considerable investigation. Smith et. al. (1957) noted that by using microwave techniques we may now observe heat radiations. Blackbodies in the form of lossy waveguide terminations are used to calibrate receivers in the 8-mm. wave band. We shall examine the antennae.

Most moth antennae are very stable in free flight (Callahan 1965a), and are located forward and away from the body of the flying moths. Thus, the antennae sensilla, displayed against the nighttime background, are relatively free of any interference from the thermal emission of the moth's body.

In the microwave region of radio there are three tuneable frequency configurations called resonant cavities, which are classified according to their physical construction. They are the coaxial resonator, the waveguide cavity, and the rhumbatron or doughnut-shaped cavity. They take the shape of cylinders, rectangular prisms, or spheres. Rectangular waveguides are commonly used as resonant cavity devices in microwave radar. The cylindrical hollow waveguide and cylindrical coaxial resonator are the two configurations most nearly resembling the structural form of the antennal sensilla.

The present state of antennal morphology indicates that although some sensory sensilla may be hollow, others have processes originating at the sensory nerve cell that are channeled through a cuticular sheath and end in pores at the spine cuticle (Schneider 1964). If we consider these two types electrically, the former may resonate as hollow waveguides and the latter as coaxial resonators. Either type might also be filled with a liquid or other substance and thus be similar to a solid or liquid-filled dielectric resonator.

Okress (1965) stated, "In the case of solid or liquid dielectric waveguides, the electromagnetic energy exists in both solid or liquid dielectric and the surrounding air. For high real dielectric constants and for frequencies well above the cut-off valve, the energy is essentially confined in the solid or liquid dielectric. Since the cut-off wavelength depends upon the dielectric constant, no simple expression as previously given for the metallic case is possible.

"For single lobed directional radiators the asymmetric hybrid $HE_{11}$ mode in dielectric waveguide has similar field configuration to that of the dominant ($H_{11}$) mode in hollow circular metal waveguide, except that the former ($HE_{11}$) has no cut-off (i. e., propagates at all frequencies). However, there is cut-off behavior with respect to all, including the $H_{01}$ and $E_{01}$, other modes.

"In the case of the hollow dielectric cylinder waveguide, modes arise corresponding to those of the solid dielectric rod, but characterized by greater cut-off frequencies. However, in the case of the $HE_{11}$ mode, no cut-off frequency exists again. Furthermore, hollow dielectric cylindrical waveguide can support a single mode (i. e., the fundamental $HE_{11}$ mode). This is especially important for use as an antenna. This is done by reducing the ratio of wall thickness to real dielectric constant to a sufficiently small value. Furthermore, for thin wall dielectric waveguide essentially single-lobed radiation pattern may be realized. This follows for the $HE_{11}$ mode when the wall thickness is small enough to make the hollow dielectric waveguide beyond cut-off for all other modes.

"It is for these reasons important to determine whether the insect's antennae are filled with high or low or no real dielectric constant liquid (e.g., water). It is also important to determine the real and complex dielectric constants of the dielectric antennae tubes and liquids, if any, contained therein".

Generally speaking, if we allow the inner conductor in a coaxial line to decrease in size we can eventually remove it, and the magnetic field will be self-supporting. This then becomes the $H_{01}$ mode in a circular waveguide (fig. 3). The resonant modes, which correspond to the lowest possible generated electromagnetic frequency, are labeled $E_0$ and $H_0$ modes. They are the lowest of an infinite number of frequencies at which a cavity will resonate. The cutoff wavelength of all modes in a circular waveguide is $\lambda c = \frac{2 \pi a.}{S}$ The cutoff wavelength for the $H_{01}$ mode in a circular waveguide is $\lambda c = 1.64$ a.

E- waves (fig. 4) are produced by calculating modes in rectangular waveguides and allowing the configuration to change from rectangular to circular. Where the configuration is changed, it may be necessary to have circular waveguides of different sizes for different modes if we are considering the same wavelength energy. The different sizes would be necessary, because the cutoff wavelength changes and the circular waveguide must be able to propagate the energy of the wavelength in the rectangular waveguide (Mariner 1961). Such is, of course, exactly what we have in the moth antennae. There are many different antennal sensilla and certain of them are of variable lengths in graduated steps (Callahan 1967).

E- modes have an electric field parallel to the axis of the cavity (Young 1960). The $E_{01}$ mode has a field that is constant with an angle a half wavelength in width along the diameter and a full wavelength along the axis. The $E_{01}$ mode of the cylindrical cavity has a resonant frequency dependent on only one dimension, that of the radius; the other dimensions are not required to fit any half or whole wave configuration. In calculating the $E_{01}$ mode, the resonant frequency and radius of the resonant cavity fit the formula where $\lambda c = 2.613$ a.

Whenever we use this formula to calculate the resonant frequency for antennal sensilla, labial spines, or larval spines (fig. 5), we always end up in the IR region, invariably in the region of the near, intermediate (IIR) or far infrared (FIR) from 1.5 $\mu$ and 1 mm. These calculations are used as an example and not as fact because exact configurations are not known. Measurements are at present being made with a scanning

electron microscope. The transfer of energy from the spine transducers to the central nervous system would obviously involve no image conversion, but the signal could be used effectively in the same manner as a loop antenna in the radio frequencies. In such a system there would be either a null or a reinforced signal strength, depending on the position of the paired antennae in relation to the signal. Griffith (1968) constructed a large-scale model of a dielectric tubular antennae of a corn earworm moth sensilla in the 4 GHz (7. 5 cm) region. It proved to operate as predicted as an efficient high gain antennae.

## ANTENNAE SENSILLAE ARRAYS

Schneider (1968) reflects the attitude of the majority of insect electrophysiologists toward theories of insect olfaction. He states (page 208), "While some of the principles of olfactory receptor function as used in the theories appear to be relevant, none so far is able to explain the known facts in a satisfactory way. Many of the so-called odor theories are only more or less elegant speculations with varying degrees of heuristic value". In light of electrical and dielectrical properties of the insect cuticle (Callahan 1967) and the fit of the diverse forms of insect sensillae to known waveguide configurations, this statement is overly pessimistic. Furthermore, there is experimental proof that dielectric sensillae respond to pure frequencies (Callahan 1968 and Bruce 1969). Significant dielectric waveguide configurations (Weinstein 1969) are ring-shaped, found on the antennae of the Cecidomyidae, slit like on the forelegs of ticks (fig. 6), tapered on moths and beetles (figs. 7-9), and mosquito antennae (fig. 12a), helical on the wolf spider (Callahan 1967), and ants, transparent, the ocelli of most insects (fig. 10) and eyes of spiders (fig. 11), and corrugated on the antennae and legs of moths and legs of mosquitoes (fig. 12b).

The corrugated configuration is quite common in insects and is particularly significant for as Weinstein points out, "Slow waves can propagate also in other periodic structures (Weinstein 1966, Sections 48-51). The three-dimensional analogy of this structure is the corrugated rod (Weinstein 1957, Section 70) which also - under certain conditions - supports the propagation of surface waves". Such dielectric periodic structures can support pure surface waves with zero (0) attenuation, if the period of structure is sufficiently small compared with the wavelength, which is true of the corrugated rods of moth legs and antennae and mosquito legs.

In 1965, the USDA funded a cooperative project with the Electronic Research Laboratory at the University of California. The protype of the scanning electron microscope was first used on that project to examine the fine detail of the insect antennae sensillae (Griffith 1968, Callahan 1969). Over the ensuing five years, the scanning electron microscope has been developed commercially and will surely become the single most important tool of the insect morphologist and taxonomist. We now have at our disposal a technique for observing in "close-up" detail the remarkable form of insect sensory mechanisms. In our laboratory, we plan to use the scanning microscope to quickly and accurately measure the length of the antennae sensillae by feeding the output of the video monitor into a computer. Utilizing this technique, we will be able to obtain accurate data for use in waveguide and spacing array formula (Callahan 1965b).

Callahan (1967) has shown that the epicuticle can act as a thermoelectret and hold both homo- and hetero-charges and that the antennae is definitely a charged dielectric. The degree to which sensillae dielectric can charge is best illustrated in fig. 13 of the eye of the red flour beetle, Tribolium castaneum (Herbst). It will be noted that although the electron beam has not charged up the facets of the eye, the minute dielectric spines between the facets are highly charged as indicated by their whiteness. They fairly glow in the electron beam. No one is sure of the function of the eye sensillae, but hopefully we can utilize our scope to also measure electrical charges. The same charge phenomenon is noted on the rod like sensors of the saw tooth grain beetle, Oryzaephilus surinamensis (L.) palpus (fig. 14b). Presumably, these are the complex taste sensors of the beetle.

As more and more insects are scanned new configurations of dielectric sensors will be discovered. In a very few weeks, we have discovered at least seven that have not been described in the literature or are incomplete and inaccurately described, such as the Hallers organ, or slit dielectric cavity, as we term it, on the lone star tick, Amblyomma americanum (L.). Since we can now both see and measure the Hallers organ accurately, it is possible to apply open waveguide theory to a frequency fit of it. Beneath the slit are unique dielectric sensillae. In waveguides with narrow longitudinal slits, the modes with the smallest radiation losses are the electric (E) mode (fig. 4). Such modes induce only longitudinal currents on the walls and the configuration can be treated as a resonant cavity. As Kiely (1953) has pointed out, a hole in a block of dielectric material is also a dielectric aerial.

The over-all array like pattern of antennae sensillae is best illustrated on the antennae of the bark beetle, Ips calligraphus (Germ.) (figs. 9a and b). The arrangement of sensillae on insect antennae, so far studied in our laboratory, have been in array like patterns. Sensillae arrays are the norm not the exception on the insect antennae and are indicative of multiplicative signal-processing antennae as pointed out in the introduction.

Interesting sensillae on the scale-like antennae of the red flour beetle are forked or tripod shaped and set in deep pits (fig. 8). These have much in common with supergain ring antennae, Cecidomyidae have closed loops on their antennae, and can be studied as open rings. Such dielectric antennae systems are treated mathematically as open resonators and have extremely high directivity. They are called supergain antennae because of their efficiency as antennae.

It may be, as my electrophysiological friends insist, that all these unique configuration are meaningless and that evidence by me to the contrary is circumstantial. If such is the case, then dielectric antennae engineers are designing systems and using formula that accurately describe what insects have developed on their own antennae, but with no significance to the insect's communication system.

Table 1 - IR emissivities ($\varepsilon$) for different objects at ambient temperatures (after Barnes 1963).

| Material | Emissivity |
|---|---|
| Human skin | 0.99 |
| Water | .98 |
| Green plants | .95-.97 |
| Lamp black | .95 |
| Concrete, glass | .94 |
| Paper, plastic | .92 |
| Plastics | .88 |
| Stainless steel, iron | .70 |
| Plowed field, gravel | .28-.44 |
| Polished cast iron, lead | .21-.28 |
| Chrome | .08 |
| Mirror | .02 |

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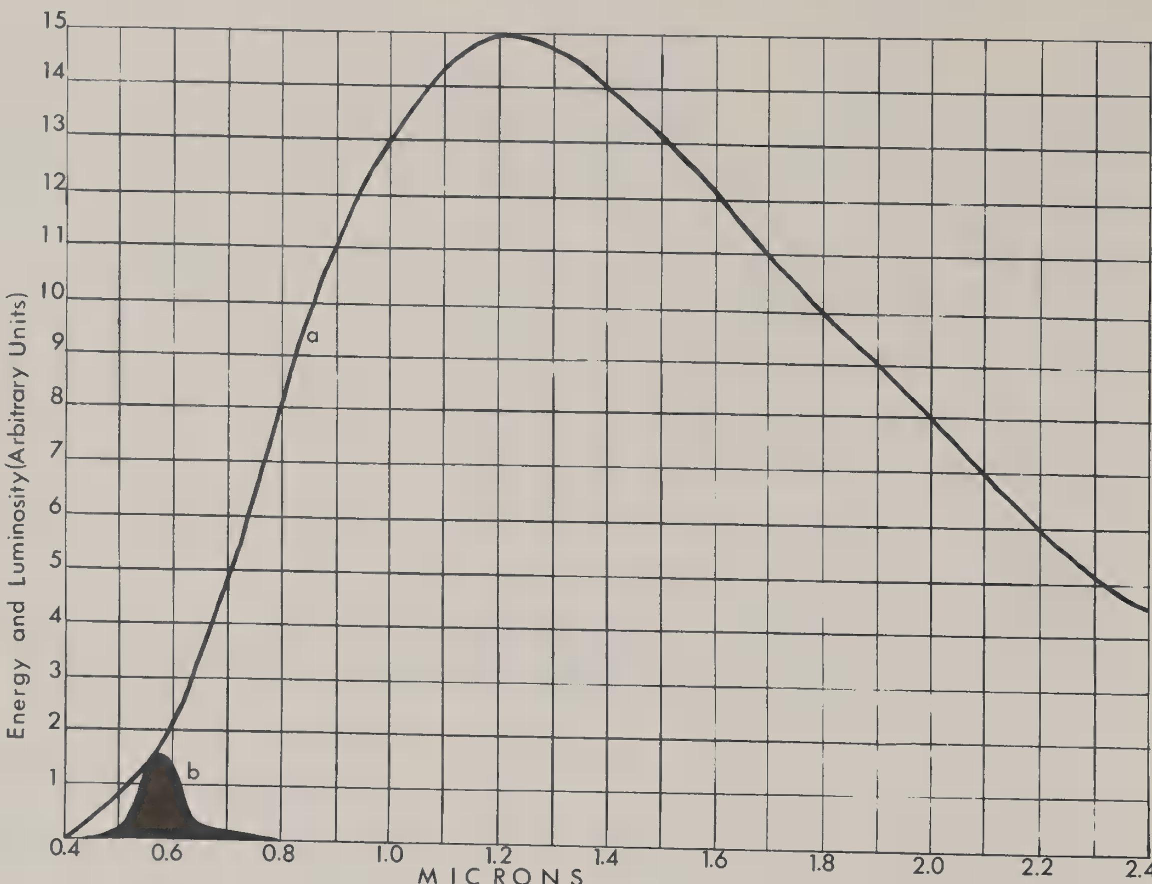
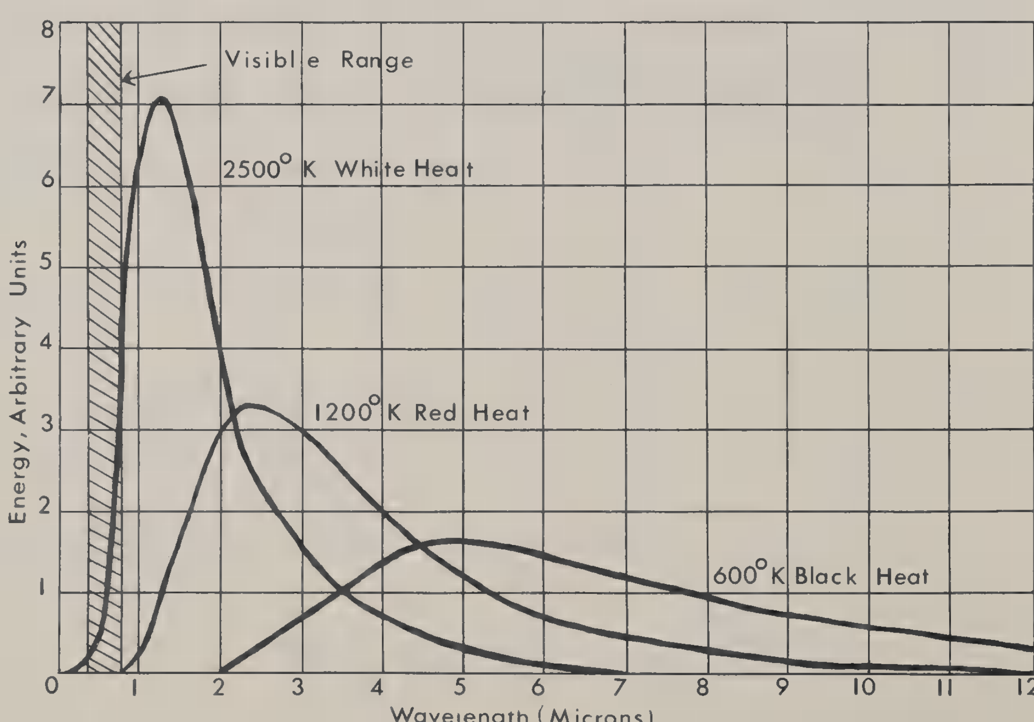



Figure 1 - Spectral energy curve (a) and luminosity curve (b) of a tungsten filament at 2200$^{\circ}$ K (after Schilling 1940).

Figure 2 - Increase in mean wavelength of radiation as temperature is reduced (after Summer 1962).



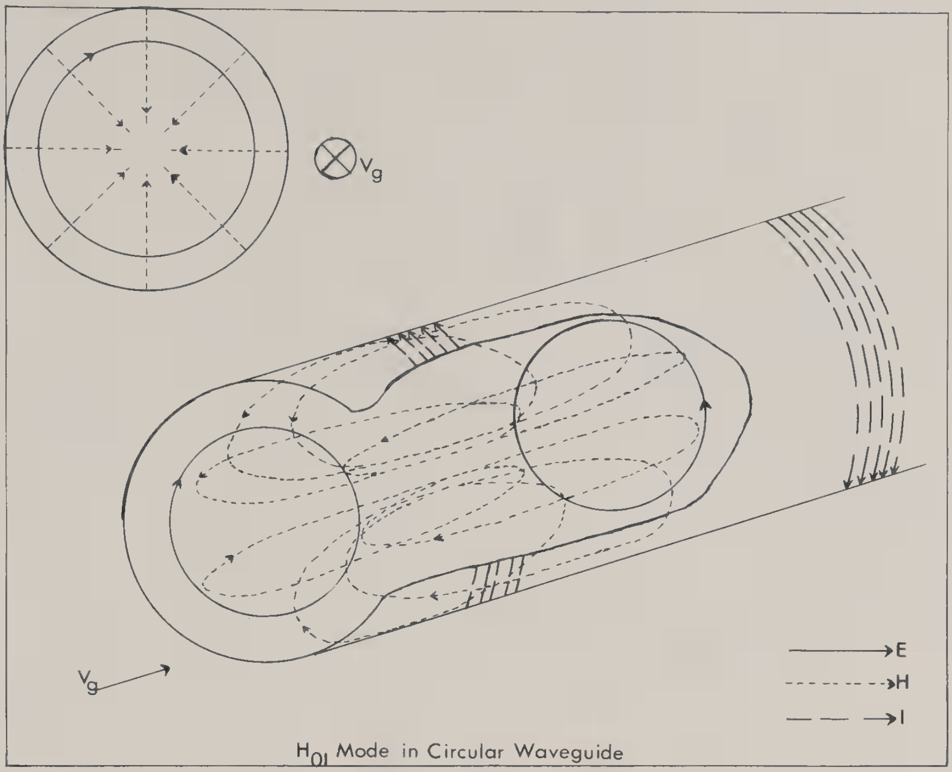
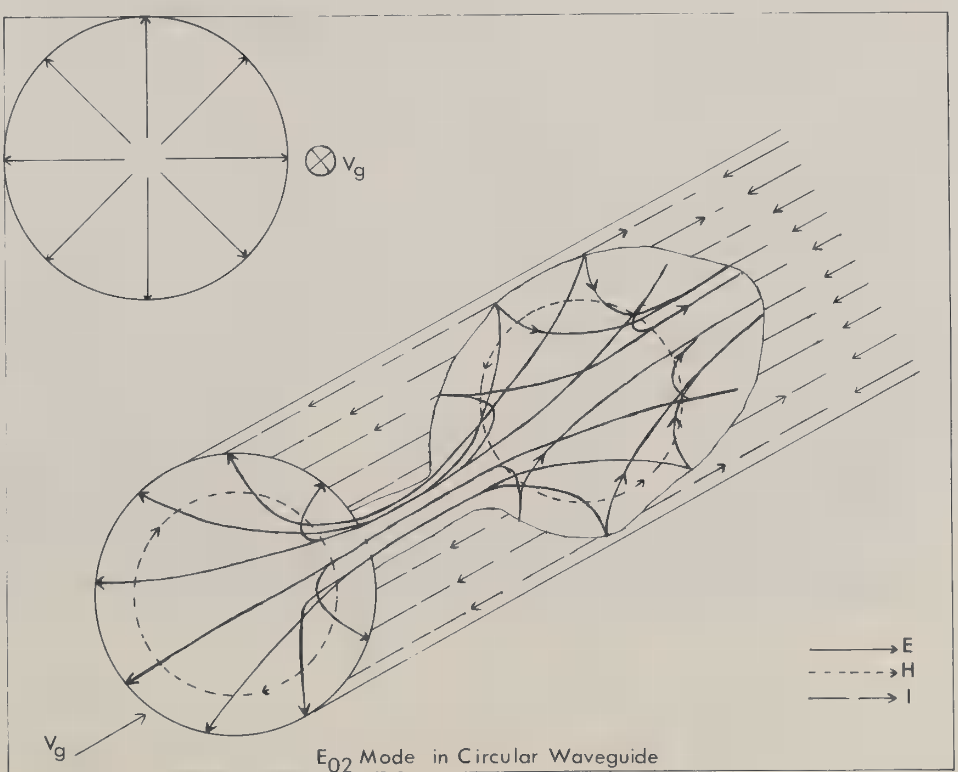



Figure 3 - $H_{01}$ mode in hollow circular waveguide (After Mariner 1961).

Figure 4 - $E_{02}$ mode in hollow circular waveguide (after Mariner 1961).



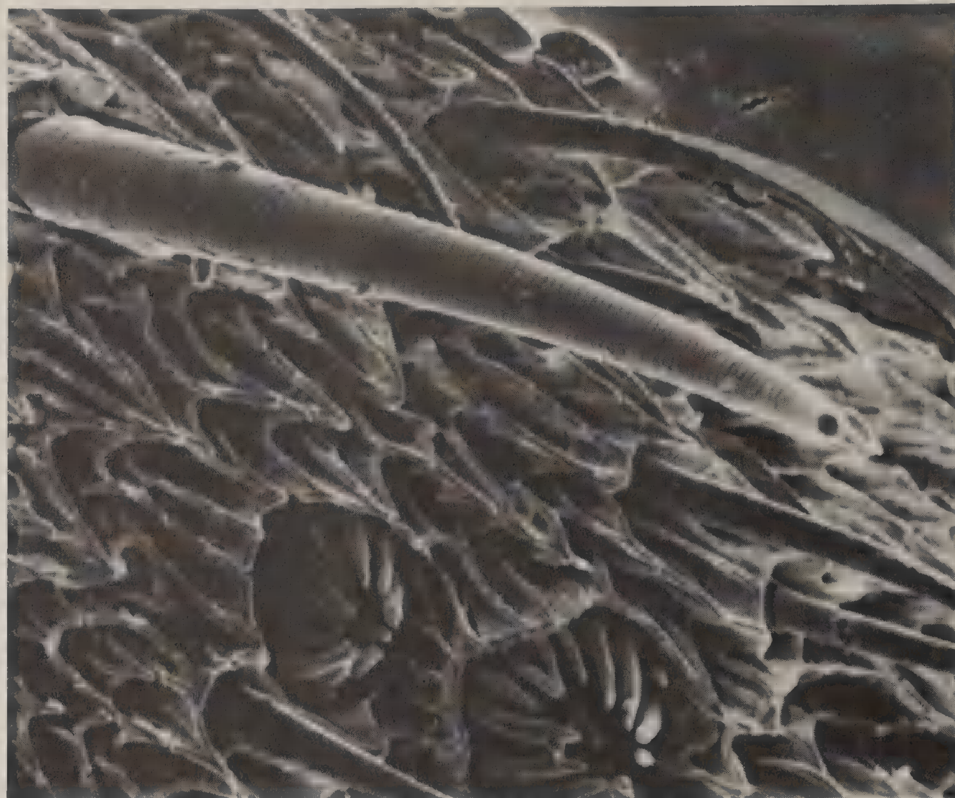


Figure 6 - Haller's organ (500X) on the foreleg of the lone-star tick, Amblyomma americanum (L.). This organ which has not been accurately described consists of a slit in a thin dome that covers an array of dielectric spines. In antennae terminology, it would be called an open waveguide with a slit configuration.

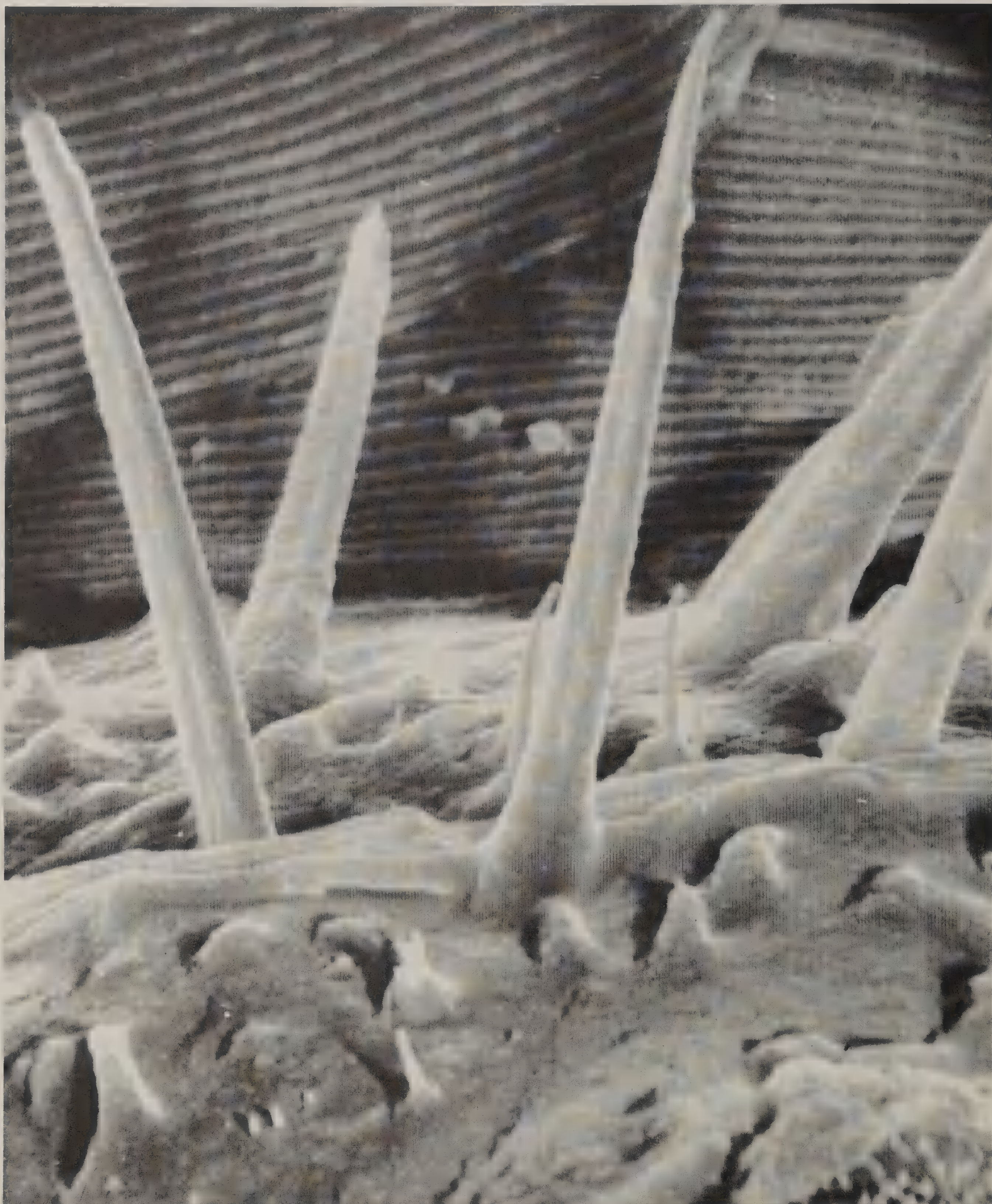


Figure 7 - Scope dome sensors on the scope of the cabbage looper antennae (2000X). These sensors are similar to tapered dielectric rod antennae. In the background are antennae scales. They are probably proprioceptors but may have a waveguide function.

Figure 8 - Antennae of the red flour beetle, Tribolium castoneum (Herbst) (1000X). This antennae has long curved corrugated sensillae and forked or tripod types of open waveguides, their closed counter part would be ring supergain antennae as found in the diptera family Cecidomyidae.

Figure 9a - Antennae of the bark beetle, Ips calligraphus (Germ.), (200X), showing the array like pattern of the tapered dielectric sensillae.

Figure 9b - Antennae of the bark beetle, Ips calligraphus (Germ.), (2000X), showing the array like pattern of the tapered dielectric sensillae.

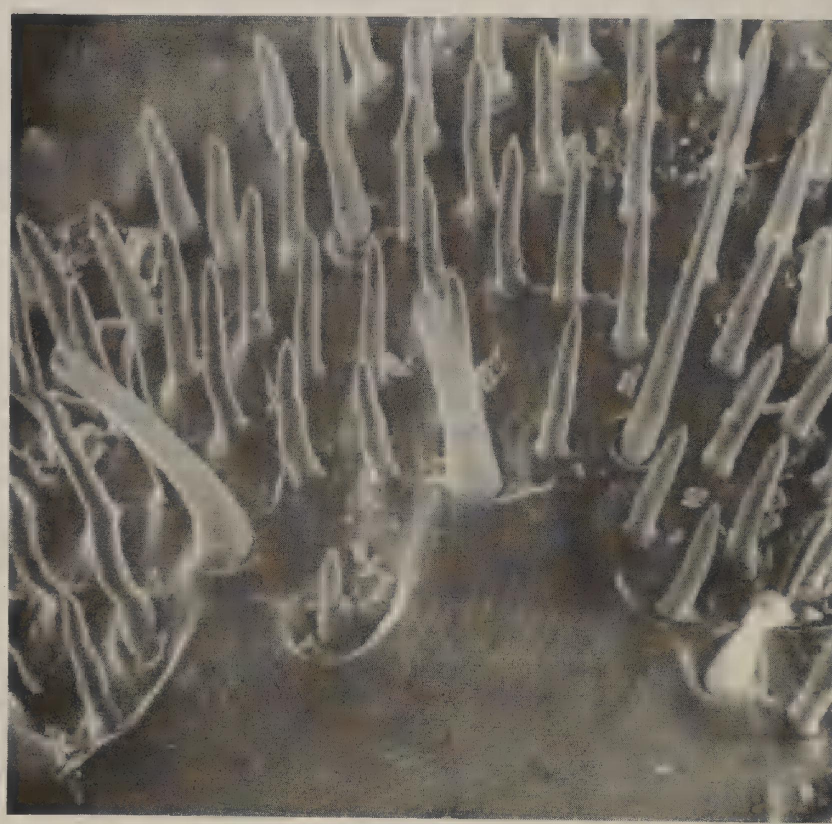


Figure 10 - Cabbage looper larvae ocelli (500X), these could be treated by antennae theory as partially transparent open waveguides.

Figure 11 - Dwarf spider, Ceratinopsis anglicana (Hentz), showing simple eyes and tapered spines on the head, (100X).

Figure 12a - Antennae of Aedes aegypti (L.) female, (1000X) showing the short curved tapered sensillae and base of the long heavy rod like sensillae.

Figure 12b - Corrugated rod sensillae on the hind leg of Aedes aegypti (L.) (2000X). The corrugated rod is an open waveguide that supports the propagation of "pure" surface waves with zero (0) attenuation.

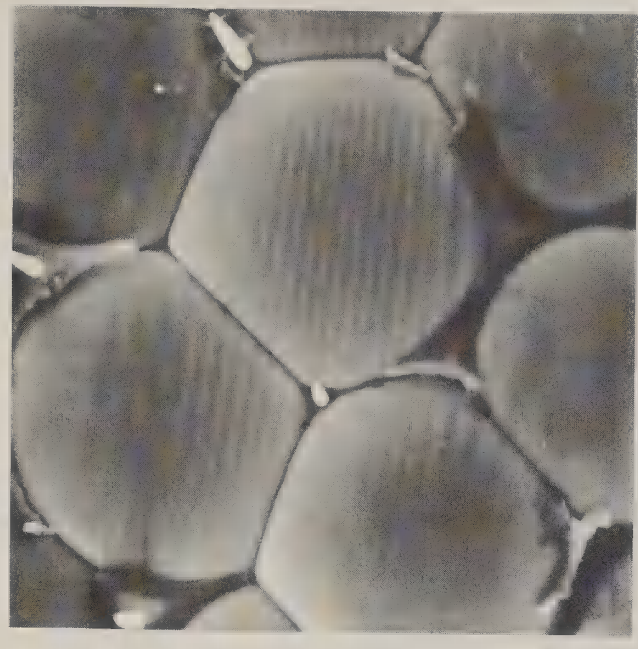


Figure 13 - Eye facets of the red flour beetle, Tribolium castoneum (Herbst) (1000X). The function of the dielectric spines between the facets is unknown but they charge up much quicker than the corneal lens system, as shown by their whiteness.

Figure 14a- Palpi of the saw-toothed grain beetle, Oryzaephilus surinamensis (L).

Figure 14b - Note how the sensors at the blunt end charge up in the electron beam.


Panel on Detection - L to R, C. R. Grady, Pest Control Forester, N. C. Forest Service; T. H. Flavell, Entomologist, Zone 1, Asheville, N. C.; C. W. Chellman, Entomologist, Florida Forest Service; G. N. Mason, Pest Control Forester, Texas Forest Service; J. C. Bell, Survey Specialist, Asheville, N. C.; W. M. Ciesla (Moderator) Zone Supervisor, Zone 2, Alexandria, Louisiana.

## APPLICATION OF REMOTE SENSING IN FUTURE SURVEYS

Joseph C. Bell, Jr. 1/

Remote sensing methods are among our most valuable forest insect and disease survey tools. We have been using remote sensing, in one form or another, since our first insect and disease survey. Today I would like to discuss some of the remote sensing techniques and systems which will become widely used in operational surveys during the next ten years.

### PROMISING TECHNIQUES

Photography has been and will continue to be one of the best means of gathering insect and disease survey data. It is fast, economical, and it is adaptable to many resource management problems. Most of you are familiar with the aerial photographic survey using color infrared

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film. It is not a new method. It was described in detail at our 1967 Work Conference. There are, however, some recent developments which may make it even more useful.

Simultaneous photographic subsampling is one technique which will increase our efficiency and reduce our survey costs. This is done by using two cameras both pulsed by the same intervelometer. A large format reconnaissance or mapping camera with a wide angle lens will provide broad coverage showing the larger spots of dying trees. The second camera will have a small format and a long focal length lens. It will take a large scale photograph of the same trees shown in the center of each large format, wide angle photograph (fig. 1). This subsample photography will provide data on single dying trees and small groups containing two or three dying trees. As with all other types of aerial surveys, a portion of the large scale and small scale photographs showing dying trees will have to be visited on the ground to determine the causal agent. Using such a technique will make possible much closer surveillance at reduced costs.

The unique properties of color infrared film have helped make the aerial photographic survey an operational success. These properties have not yet been completely exploited. Conifers which have been damaged have a lower near-infrared reflectance than healthy trees (Murtha and Hamilton, 1969). Color infrared densitometry can take advantage of this. Color infrared photography has been used to locate Fomes annosus (Fr.) Cke. infected pine trees which appeared healthy. This was done by making red-filter optical density measurements of their images. The cyan dye layer of those trees nearer the infection center was more dense than for the healthy trees in the stand (Murtha and Kippen, 1969). The color infrared densitometry technique will probably be of limited value against fast-moving insect pests, but it should be very useful against pathogens, particularly in forest plantations.

## MULTIBAND PHOTOGRAPHY

Most of the color photography that we see is produced by the subtractive color process. The colors in the photograph subtract from the viewing light the unwanted colors and the remaining light strikes the observers eye producing the sensation of color (Yost and Wenderoth, 1967).

One of the most promising survey tools for the 70's is multiband photography using additive color projection techniques. Multiband photography uses a special camera with several lenses which takes several identical black and white pictures at the same time. These pictures are identical

except that different filters are used with each lens of the camera (fig. 2). The film is then very carefully processed to a positive.

The resulting simultaneous photographs are each put into a different projector equipped with a blue, green, or red filter and projected on the same screen. The projectors are adjusted so that the images overlap one another (fig. 3). The result is a color reproduction of the original scene using black and white photography. For convenience, the several projectors are often enclosed in a box with mirrors and a rear projection screen. The result is an additive color viewer. By adjusting the intensities of the different projection bulbs, by changing filters, and by making other adjustments in the projection system, the viewer can be made to exactly reproduce the colors present in the original scene or make any color combinations desired. Trees can look like the real thing or they can look red like a color infrared photograph. Or they can be made any color you prefer. The color additive viewer is basically a data handling system. It makes it possible to assemble large amounts of data into a meaningful form.

Multiband photography gives much better discrimination than ordinary subtractive color photography (Anderson, 1969). Objects which look very much alike or even identical to the human eye can often be separated from one another. The choice of filters is the key to very fine discrimination. Many tree species look identical on ordinary photography. They might be easily separable using several narrow band filter combinations which would show the tree in the light from narrow portions of the total photographic spectrum. Other discrimination problems come to mind when we think of forest resources protection. Lightning struck trees, growth impact appraisal, fall coloration, oaks in winter, and cumulative damage inventory are just a few. This power of increased discrimination will make multiband photography an important forest survey tool in the years to come.

## AUTOMATIC REMOTE SENSING

Last year, I was very fortunate to be able to do some work at the Laboratory for Applications of Remote Sensing (LARS) at Purdue University. I would like to close with a brief description of the LARS system of automatic remote multispectral sensing and show you some of our classification results.

The optical-mechanical scanner is a sensing device which uses a rapidly rotating mirror to gather light or spectral energy from a small point on the ground below. The scanner is usually mounted in an aircraft. As

the mirror rotates, the scanner looks at a narrow strip of terrain below the aircraft. This side-to-side motion together with the forward motion of the aircraft permits continuous coverage of a large area of terrain in a short period of time. The size of the area looked at by the scanner at any one instant of time varies with the altitude of the aircraft. Usually this would be a spot 3 foot$^2$ from 1,000 feet (or 12 Ft.$^2$ from 4,000 ft., etc.).

The light picked up by the mirror system passes on to different detector units which are sensitive to different portions of the spectrum. (Scanners may have as many as 24 different wavelength bands.) The detector units convert the spectral energy to an electrical signal which is then recorded on an analog tape recorder (Croon et al., 1968).

After the flight, the analog tape is taken into the laboratory and converted to digital form. The data can then be displayed in a form similar to a black and white photograph. This imagery together with aerial photographs and other ground truth information is used to train the digital computer prior to the actual classifications. The training process consists of showing the computer small areas each containing a material of particular interest e.g., corn, wheat, conifers, hardwoods, etc. (Much of this training may have already been done on a previous flight.) Various computer subprograms are used to help choose the best possible training samples and the best possible wavelength bands for the final classification. The classification goes something like this. The computer looks at the data from each point on the ground in each of those wavelength bands you choose, refers to the training materials which it knows about, decides which one it is most like, and then prints out the symbol representing that material. After the classification is complete, the computer summarizes the totals of each material present.

The classification studies that I worked on include a simple familiarization study, a forest tree classification and one insect infestation classification. The object of all of these studies was to familiarize me with the LARS system. They are interesting not because of their content, but because of their implications. The object of the forest tree classification was to separate hardwoods from conifers in a small forested area. The classification was rather limited but the results did imply that some species such as white pine and yellow poplar as well as quite narrowly defined species groupings can be successfully classified (fig. 4). The possibilities in forest inventory work alone might easily justify the scanner-computer approach.

I was very fortunate to be able to work with a scanner data covering a barkbeetle outbreak. This was generously provided by F. P. Weber, Research Forester with U.S. Forest Service, Remote Sensing Research Project at Berkeley. This classification was incomplete because of limited time but it did show that the LARS system could easily classify barkbeetle infested pines which were visible to the unaided observer. Previsual detection of green infested trees cannot be ruled out.

The speed with which the optical-mechanical scanner and the high speed electronic computer can gather and process mountains of data makes the LARS system seem a likely tool for future operational forest insect and disease surveys.

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# COLOR INFRARED PHOTOGRAPHY AS AN INDICATOR OF EARLY FOMES ANNOSUS INFECTION

Garland N. Mason [1/]

Each year, the forest manager is faced with the problem of increased acreage being taken from production through urban development, agriculture, and reservoir and highway construction. It is, therefore, becoming increasingly important that our existing forest resource be managed more effectively to insure maximum returns from the investment.

An important part of effective management is preventing losses to fire, insects, and diseases. Current figures reveal that insects and diseases in the United States account for a loss equal to the annual growth and exceeding the losses from fire by seven times. In order to control these pests, they must be detected in their early stages before wide spread outbreaks can develop.

Previsual detection is a term which has developed during the past 5 - 10 years, primarily as a result of remote sensing research with agricultural and citrus crops (3). Dramatic successes in previsual detection of abnormalities in these crops created an increased interest in forestry applications.

Thus far, to my knowledge, only three attempts have offered promise of detecting early stress in coniferous forest trees. Probably the most successful results were obtained by measuring early morning temperature emission with an infrared radiometer (4). This is a non-photographic technique and, at present, does not offer the advantage of rapid data acquisition demanded by our situation. The other successes have used a photographic means of detection; one in visually detecting Fomes annosus in white pine on infrared photography (1), the other using microdensitometer measurements of photographic density (2). These attempts at previsual detection have either not been tried, or have been unsuccessful on Southern pine, where our most intensive forest management is being practiced.

Many Ektachrome Infrared photographs of stressed trees have been taken by interested workers all over the United States, with perhaps unrecognized success. I feel that we may have been asking too much from our photographs, expecting them to produce similar dramatic results, as

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obtained with agriculture and citrus crops. We may have been getting early symptom indication, without recognizing it.

Kodacolor II and Ektachrome Infrared Aero 8443, 35mm oblique photographs were taken aerially in early October, 1969 using a Nikormat camera equipped with a 55 mm Micro Nikkor Auto lens. Filter combinations with the infrared film included a Tiffen Photar # 12 (yellow), a Soligor # W14 (orange), and a Vivitar # 25 (red) filter in an attempt to cut off portions of the visible spectrum, thus stressing the infrared region. Paired photographs, of a known infection center from which detailed ground truth had been collected, were obtained from 300 and 2,300 feet above the prevailing terrain.

Seven interpreters were asked to evaluate the results. No "symptomless" infected trees were detectable on the color shots, while an average of seven, of nine known infected trees which exhibited no visual symptoms, were detected on the infrared. This is an increased efficiency of 78% over the color film. Three "healthy" trees, however, were classed as infected, based on the same evaluation. These trees may or may not be infected. No annosus sporophores were present when the ground truth was taken. Laboratory examinations are planned to confirm the presence or absence of infection in these trees.

Equal results were obtained with the orange and the yellow filter; the red filter altered the color balance, making examination uncomfortable and difficult. Camera settings of 1/125 @ f 5.6 and 1/250 @ f 3.5 proved best with all filter combinations.

The differences between apparently healthy and stressed trees is not as dramatic as that found in citrus; but is seen as minute tonal variation ranging from shades of pink to almost white. Many of you are probably saying that you see no difference in these trees and in natural differences resulting from sun angle or glare. This may be true, but the fact remains that a certain number of symptomless trees were selected by unbiased observers. This, I feel, is of significant value from the standpoint that previsual symptoms were detectable, and with advances in technique, camera systems, filtering processes, film sensitivity, and additional training of the image analyst, the technique might someday be put into operation.

You may ask - "how can we justify spending this kind of money to detect pest problems which may be uncontrollable, or which may remain for weeks after detection before control measures are initiated?"

An example of a possible application is foreseen with a pest problem which is very familiar to us in East Texas--the Southern pine beetle. The logical time to control an insect outbreak is to attack when the population is in natural endemic or seasonal low levels. Winter Southern pine beetle levels in East Texas characteristically drop to almost undetectable proportions.

The problem, however, in winter control of Southern pine beetles is the larger number of green infested trees, which may surround a single or multiple tree infestation, but which fade very slowly because of decreased transpiration resulting from cool, moist atmospheric conditions. The cost involved in using a more sophisticated means of detection would be partially, if not completely offset, by the additional cost required in conventional detection and control of many more spots during the peak season of activity; with the added advantage of saving those trees which would be killed later in the season.

As you know, Ektachrome Infrared Aero 8443, currently offers the advantages of excellent haze penetration and hardwood-pine type differentiation. In earlier photographs, taken in January 1967, of the same area as shown earlier, we were able to add the advantage of pine species distinction. It appears that perhaps we will soon be able to add previsual stress detection in conifers, at least to a limited degree, to this growing list of applications.

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# RADIOGRAPHY'S ROLE IN FOREST PEST CONTROL

T. H. Flavell [1/]

I think it is abundantly clear to everyone here that the Southeastern Area is devoting considerable time and energy toward improving the technology of forest pest detection and evaluation. Remote sensing as Joe Bell has just pointed out, may in the near future substantially reduce the time required to locate insect or disease infested trees. Hopefully this will give us much needed time to more thoroughly investigate forest pest problems and to make better decisions on what course of action should be taken.

The key to effective forest pest management decisions as we all know, is a complete understanding of the pest problem. To achieve such an understanding we need to gather more biological and ecological information in less time so that, in the event control is needed, we will have as much time as possible to complete it before the situation gets out of hand. Thus we need to reduce the time required to make a biological evaluation in order to realize fully the benefits promised by remote sensing.

Radiography is one of the tools which we are now using to increase our speed in handling samples of insect infested material and at the same time improve the quantity and quality of the data.

My purpose here today is not to make x-ray technicians out of you, there are innumberable publications on that subject already. Rather, I hope to be able to arouse your interest in the use of radiography so that you will go home and explore the possible uses for it in your own work, and in so doing increase our knowledge on the uses and techniques of radiography in forest entomology and pathology.

When you think about it, radiography is a logical tool for forest entomologists. Many of the organisms we work with spend most, if not all, of their life cycles secluded from view. For example, bark beetles, tip moths, wood borers, twig and shoot borers, and cone and seed insects all present their own peculiar problem to the entomologist trying to find them and evaluate their damage potential. Bark beetles are a classic case in point. When I first started to work for the Division of Forest Pest Control in 1965 the standard procedure for determining the density of southern pine beetle broods was to shave a one-tenth foot square sample of infested bark with a knife and carefully count the number of insects

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as they occurred in the bark. This was a time consuming, morale destroying and often bloody job. Similarly, our procedure for sampling cone and seed insects called for slicing cones longitudinally with a home-made guillotine-like contraption and examining the face of the resulting halves for insects or damage. While the results from such a sample were quite comparable from year to year, they did not accurately measure the insect population for any one year, and because of the destructive nature of the sample rearing the insects we did find were usually impossible. The situation was much the same for tip moths. It was a relatively simple matter to count the number of infested tips, but to determine the number of tip moths actually in each tip and to get an estimate of their parasite population was quite another matter. As for wood borers, most of the ones causing economic damage were in hardwoods and as I recall, only a very few people gave a damn about southern hardwoods in 1965. I don't need to tell you the picture has changed significantly since then and with it our need for a technique to sample and evaluate hardwood borer populations.

In fact the whole picture of forest pest control is changing. At present it looks as though chemical pesticides will be less and less available to us in the future. We will have to rely on alternative techniques to manage our pest populations in order to keep them below the economic damage threshold. This will require a more sophisticated knowledge of the biology and ecology of our pests, and certainly much more accurate estimates of their actual numbers, and the numbers of their natural enemies.

This is where such techniques as radiography come in. With bark beetles for example, Fatzinger and Dixon, (1962) and DeMars, Jr. (1963) compared the efficiency of hand dissection and radiographic methods for determining the number of southern pine beetle and western pine beetle broods in a bark sample. Essentially, their conclusions were the same, ie., that radiography gave a more accurate estimate of the number of insects in a bark sample, but that it was less accurate in determining the stages or condition of the insects. Fatzinger and Dixon also found that it took about 1.44 radiographic samples to equal the precision of one hand dissected sample. As for the efficiency of the two methods, in both cases radiography saved time and money. DeMars, Jr. found that with 8 x 10 inch bark samples "hand dissection took eight times as long and was four and one-third times as expensive as the radiographic method of estimating bark beetle numbers". Even with the increased number of samples required for equal precision Fatzinger and Dixon's study with southern pine beetle indicated that it was 3.04 times more expensive to hand dissect bark samples as to radiograph them.

The most important point which both of these papers made, to me at least, was that radiography allowed more samples to be taken and processed in the same length of time that we were spending hand dissecting them. And, as Fatzinger and Dixon concluded, and as we all know, "when more samples are taken, more confidence can be placed in population estimates derived from these samples".

As I mentioned before, the future will certainly demand more intensive biological evaluations. Pest control scientists must shift their primary objective to the management rather than "control" of our forest pests. To do this we must have not only a good estimate of the numbers of the pest species involved, but also of their parasites and predators. The usefullness of radiography along these lines has barely been touched upon. Holling (1957) was among the first to use x-rays for this purpose when he needed to separate healthy, diseased and parasitized sawfly prepupae for a study to determine the reaction of small mammal predators to these various classes of cocoons. Obviously radiography fulfilled the need for a non-destructive examination of the cocoons to be used in the study.

The fact that radiography, as we use it, is essentially non-destructive is a point which should not be overlooked, particularly in biological control work. I am reminded of an incident involving the introduction of a predator to help control the balsam woolly aphid which has devastated the fraser fir in the southern Appalachians, particularly around my home city of Asheville, N.C. At any rate it was discovered that some of the predators in a newly arrived batch were parasitized. As I am sure you are all aware, a shipment of predators can represent a sizable investment, and this one was no exception. The problem was to isolate the parasitized individuals from the healthy in time to permit the healthy ones to be released. I'm sure you all have anticipated the answer, at least I hope you have, because I hope you are beginning to see some of the many uses which we in forest entomology and pathology have for radiography. In this case the parasitized individuals were successfully isolated and the introduction completed.

I could go on and on at some length discussing various papers on how x-rays have been used in the past to solve entomological and pathological problems. But, since the theme of this work conference is A LOOK AHEAD, I thought it might be more appropriate to spend a few moments looking at some of the possible applications of radiography in the future.

In the laboratory radiography has already done away with the need for tedious hand dissection of insect infested samples. It won't be long before an x-ray machine is considered as essential a piece of equipment in an entomology lab as a microscope is today. With it we will be examining many more samples than we are today and for the first time will have a permanent record of these samples. The permanance of a radiograph is of great importance -- because of it we can begin to accumulate a sizable body of highly comparable data on the fluctuations of many of our forest pests, and if the need should arise we can go back and look for more or different information than was originally taken from the radiograph.

With experience and refinement in technique we will also be able to make better estimates of the parasite and predator complex affecting the pest species, and probably be able to see much more clearly the role of intraspecific competition in regulating a pest population.

In the field, portable x-ray units will enable us to take samples where none existed before. What forest manager would allow you to go into a stand and dissect an adequate sample of trees for wood borers or heart rot? Unless it was a cull stand or experimental forest I dare say not many! Radiography, however, not only offers us an adequate sample under such conditions, but also will enable us to go back time and time again and resample the same trees so that we might get a better appreciation of the long term impact of these organisms on a stand.

In closing, I would like to say that we all know that forest entomology and pathology are in great need of better and quicker sampling and evaluation techniques. What I have tried to point out to you is that, in many ways radiography offers a very great potential in this area. I haven't mentioned the many technical problems that still must be solved before radiography can fulfill its promise, but in this day and age when men are tramping around on the moon, technical problems somehow do not seem overwhelming. One thing is sure, the sooner more of us become involved in radiography the sooner these technical problems will be solved.

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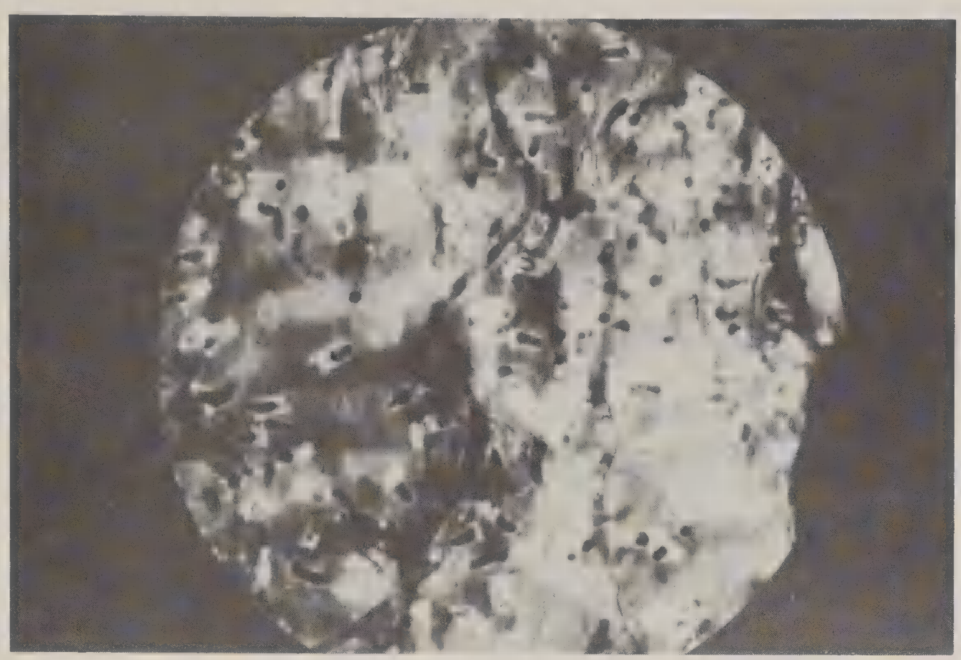

Figure 1 - Southern pine beetle larvae and adult egg galleries are clearly shown in this radiograph of infested bark.

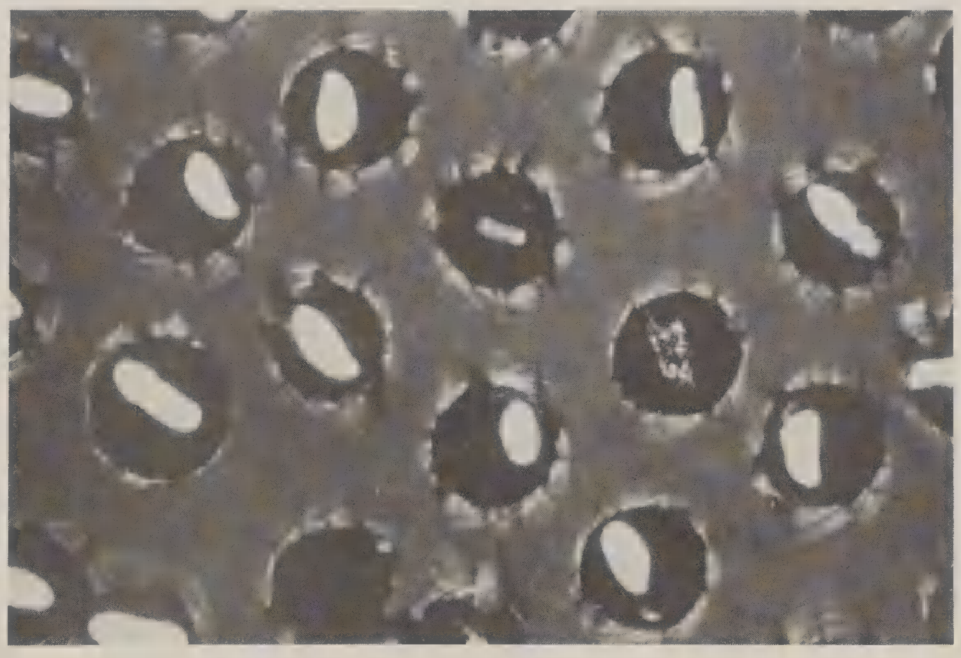

Figure 2 - Healthy, diseased and parasitized sawfly prepupae and adults are easily distinguishable in this radiograph.

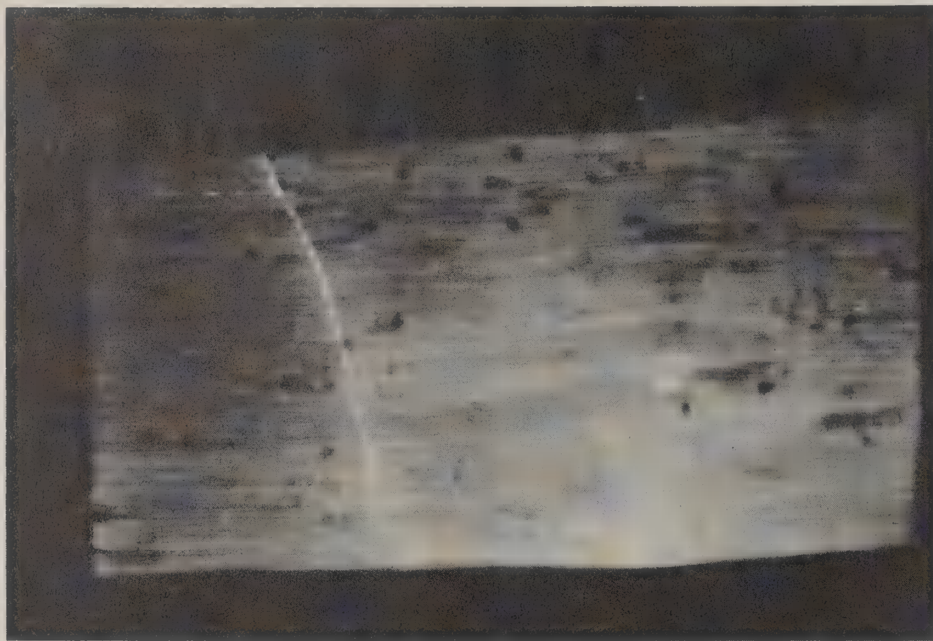

Figure 3 - The extent of a powder pest beetle infestation is easily determined through the use of radiography.

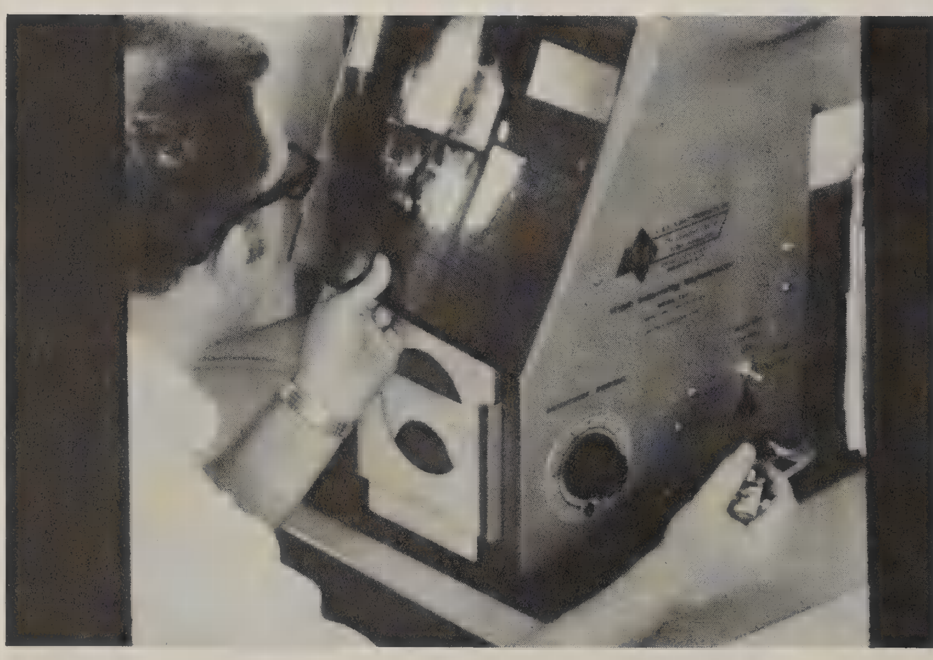

Figure 4 - An interpreter counting the number of insects revealed in a radiograph of a bark sample infested by the Southern pine beetle.

# DETECTION IN FLORIDA

Charles W. Chellman [1/]

Systematic forest pest detection began in Florida in 1957. Stimulation for detection, pest control, and an entomological staff position in the State Forest organization was caused primarily by the following two factors: (1) Extreme drought experienced in 1954, 1955, and part of 1956; (2) Several large severe fires occurred in the spring of 1956. Both of these factors contributed immensely to insect buildups and extensive monetary losses.

In the summer of 1957 aerial surveys to detect insect and disease pests were started and have been made each succeeding year. These surveys consist of a line sample technique using an operations recorder. State-wide losses are statistically calculated and the pest species involved determined by ground checking. Data for the thirteen year survey period is shown in Figures 1 and 2 and presents a good year to year comparison of losses.

This type of survey is economical and accurate, but when flight lines are ten miles apart, as we usually use, the possibility of missing a small epidemic area or trouble spot is good. To help compensate for this, unusual numbers of fading or dead single trees or spots are marked on the flight maps or taken from the recorder strip. Additional flight lines are then flown in these areas to determine the extent and seriousness of the problem.

About four years ago an expanded survey program was started. Survey flights in May and October have been made on the four State Forests totaling approximately 310,000 acres. In addition, fourteen key counties throughout the State are surveyed by the County Foresters also in May and October (Figure 3). This expanded aerial surveying provides better surveillance throughout the year and helps to develop trends in insect and disease problems. One large black turpentine beetle outbreak was discovered on State Forest lands and a large infection of pitch canker on private lands by these additional surveys.

To add to the aerial detection program, the County Foresters, of which there are thirty-five throughout the state, observe and report both important and minor pest problems in their project areas. Cooperation from industrial forest managers and other private landowners has added immensely to the over-all detection program in the state.

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Since the theme of the program is "A Look Ahead", let's discuss needs and plans--not only for detection but for control as well. Recently our State Forestry department was reorganized and the six large districts were divided into eighteen smaller districts, varying in size of from one to six counties. In theory, and so far in practice, this has permitted greater efficiency in the use of manpower and equipment to provide the required services throughout the state. From the pest control standpoint training programs are geing planned for all of the districts for this year. In the past these programs have been pretty well restricted to the professional foresters in the organization. Now all personnel will be exposed to forest insect and disease problems. It is hoped the Rangers will be able to spot unusual conditions and then report these to the County Forester or District Forester for action.

I think the greatest single need in our program is a method of Previsual Detection of insect and disease pests. With a tool like this, I believe most of our pest problems could be eliminated or greatly curtailed before they start. Equipment, procedures, and interpretation of data should be simple, accurate, and as rapid as possible, however.

Photography, particularly infra-red color, now has most of the difficulties solved, although minor problems are still encountered. Advanced photographic techniques are needed and I believe this field has unlimited possibilities.

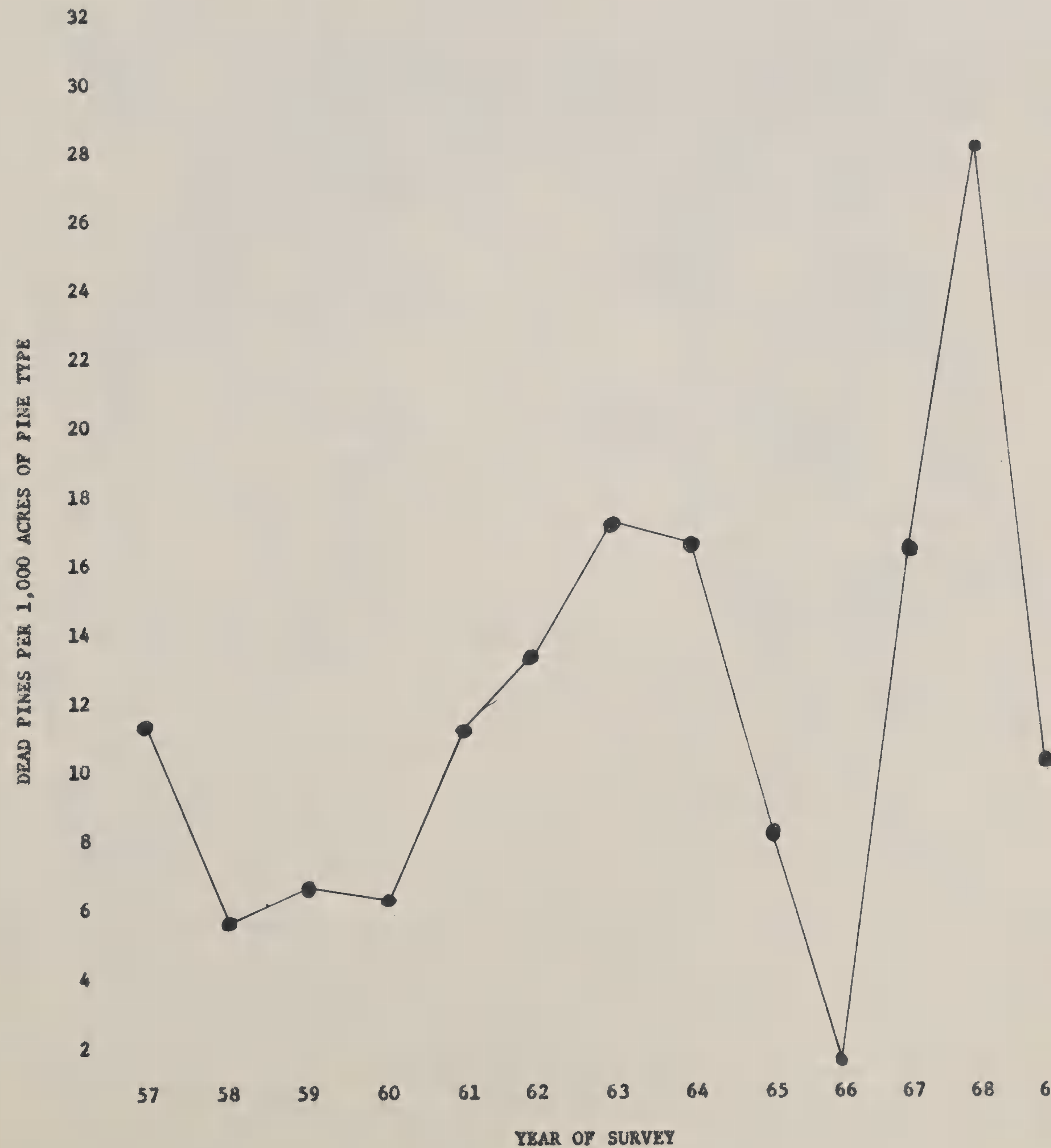
Another problem I have encountered with aerial surveys is the difficulty in observing serious pest outbreaks such as sawflies, on small trees. Infestations of sawflies of all sizes are usually overlooked in general surveys and are difficult to see from the air even after being mapped in detail on the ground. Several other pests also present similar detection problems.

Finally, immediate thought should be given to future pesticide use and other controls for forest pests. In Florida a restricted pesticides bill went into effect January 1 (copy attached). Registration and licenses are now necessary for purchase and use of over thirty-five chemicals. Several of these are further restricted to specific crops they can be used on. Members of both the House and Senate of the Florida Legislature have bills to introduce in April that propose banning DDT and the other chloronated hydrocarbons. I feel the chances are good a bill will pass and prevent the use of many of our standard forest pest controls. Also, the Federal Government, forced by Congressional action, will probably be imposing bans in the near future as well as many of the States.

In conclusion, I would like to say that detection has progressed rapidly over the years, but much is still to be done. I think we should strive for perfection, but always bearing in mind our ultimate goal - practical application.

FIGURE I

AVERAGE MORTALITY IN NORTH FLORIDA (1957 thru 1969)



FLORIDA FOREST SERVICE

TALLAHASSEE, FLORIDA

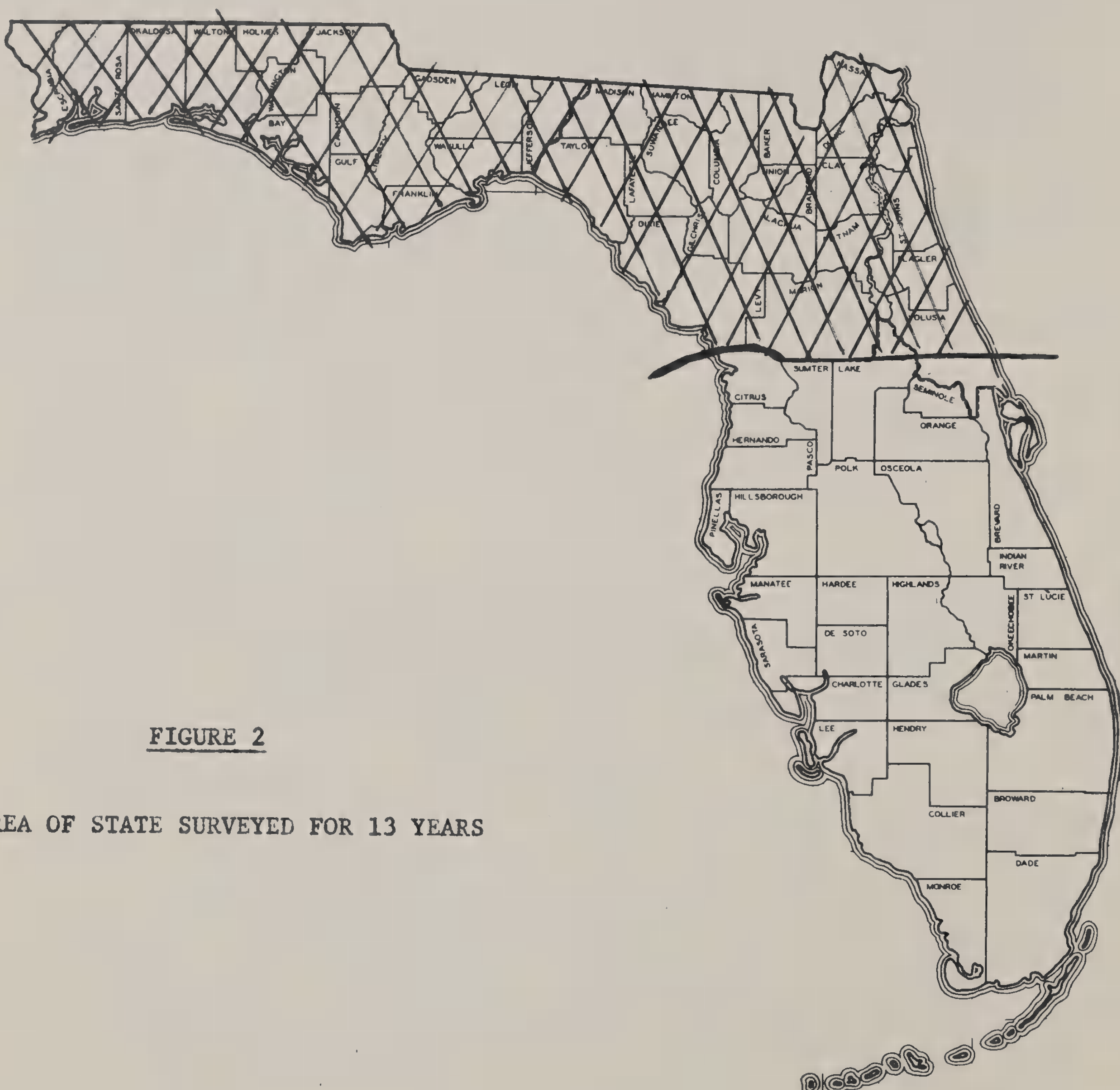



FIGURE 2

AREA OF STATE SURVEYED FOR 13 YEARS

FLORIDA FOREST SERVICE
TALLAHASSEE, FLORIDA

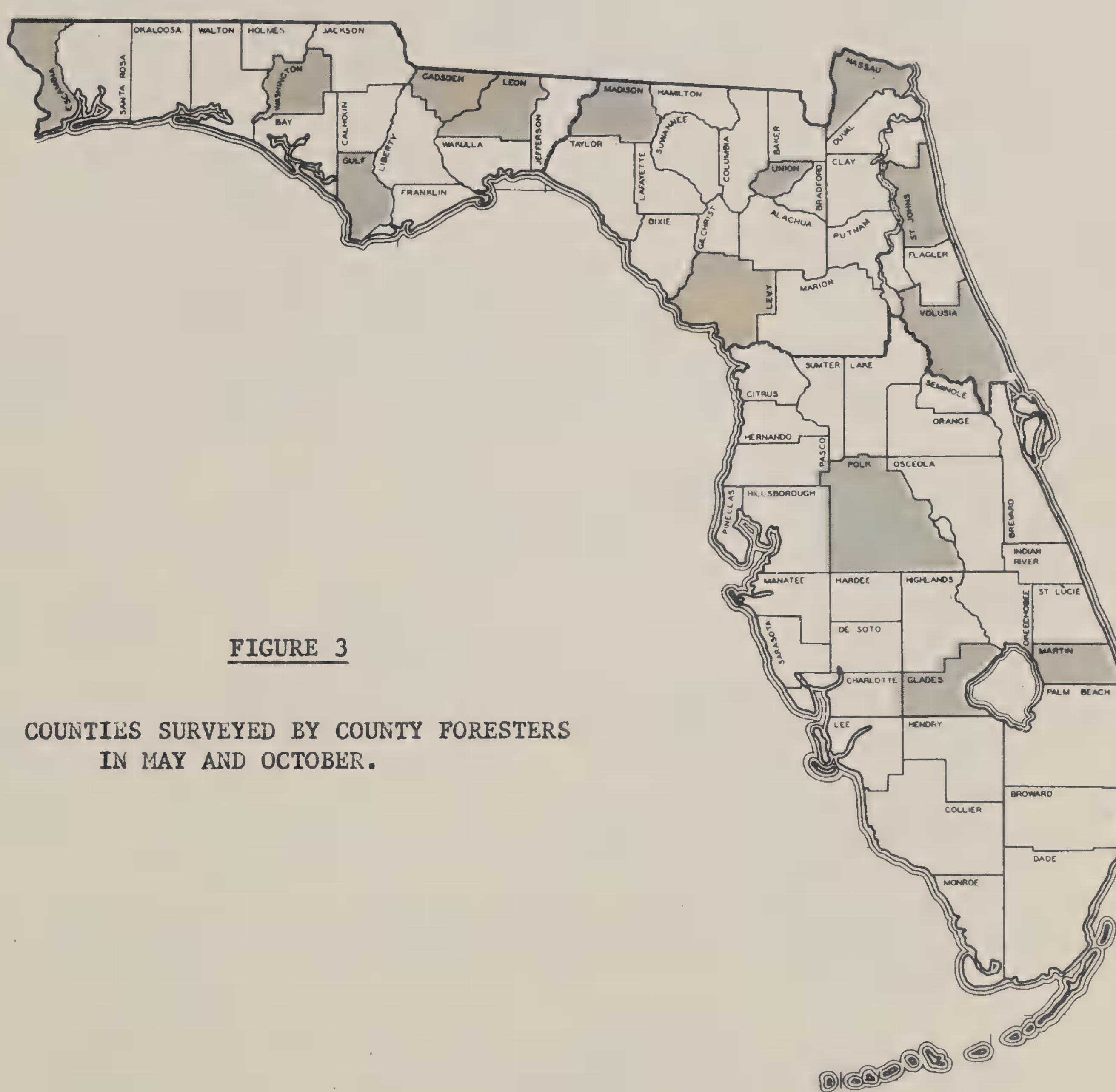



FIGURE 3

COUNTIES SURVEYED BY COUNTY FORESTERS
IN MAY AND OCTOBER.

7E-2.22 "Restricted pesticides"; definition by name; permit and license. --

(1) "RESTRICTED PESTICIDES" DESIGNATED BY NAME. -- The Commissioner finds the following highly toxic pesticides and other pesticides so hazardous to man, or his environment, animal or crop that restrictions on their sale, purchase, use or possession are necessary to protect the public:

Aldocarb (Temik) (all concentrations)
Aldrin (above 10%)
Arsenic compounds:
- (a) Inorganic insoluble (50% and above as the compound) including calcium arsenate, lead arsenate, magnesium arsenate, parisgreen.
- (b) Inorganic soluble, including arsenic trioxide (1 1/2% and above), sodium arsenite (2 % and above), and sodium arsenate (5 % and above)

Azodrin (all concentrations)
Bidrin (all concentrations)
Carbofuran (Furadan) (All concentrations except granular 10% and below)
Cyanides:
- (a) Inorganic cyanides (5% and above) (except liquid hydrogen cyanide)
- (b) Liquid hydrogen cyanide (all concentrations)

DDD (TDE) (all concentrations)
DDT (all concentrations)
Demoton (Systox) (all concentrations)
Dieldrin (above 10%)
Disulfoton (Di-Syston) (Above 2%)
Endrin (all concentrations)
EPN (0-Ethyl-0-p-nitrophenyl phenylphosphonothioate) (all concentrations)
0-ethyl s-phenyl ethylphosphonodithioate (Dyfonate) (all concentrations)
Fenosulfothion (Dasanit) (all concentrations)
Guthion (above 1.1 pound per gallon)
Heptachlor (above 10%)
Methyl bromide (all concentrations)
Methyl parathion (all concentrations)
Mevinphos (Phosdrin) (all concentrations)

Nicotine and its salts (5% and above)
Paraquat (above 0.2% cation)
Parathion (all concentrations)
Phorate (Thimet) (all concentrations)
Phosphamidon (all concentrations)
Phosphorus (white or yellow) (all concentrations)
Prophos (Mocap) (all concentrations)
Selenites and selenates (all concentrations)
Sodium fluoroacetate (1080) (all concentrations)
Strychnine and its salts (all concentrations)
TEPP (Tetraethyl pyrophosphate) (all concentrations)
Thallium compounds (all concentrations)
Toxaphene (above 10%)
Zinophos (all concentrations)

(2) PERMIT FOR PURCHASE AND USE. --

(a) Application for permit to purchase and use "restricted pesticides" shall state the specific uses (specific crops) for which the permit is requested. The permit shall state the specific uses for which it is issued.

(b) Permit to purchase and use "restricted pesticides" may be issued for any uses recommended for the pesticide in the labeling of that pesticide, which is registered with the Florida Department of Agriculture and Consumer Services or the United States Department of Agriculture, with the following limitations:

1. Aldrin shall be permitted only for use on pine seedlings; as seed treatments; as soil treatment for fruit trees, vegetables, turf; and as soil treatment for foliage, flower, fern, and woody ornamentals.

2. Arsenic Trioxide (above 1-1/2%) and Sodium arsenite (Above 2%) shall be permitted only for termite control.

3. DDD (TDE) shall be permitted only for use on cotton, corn, peanuts, soybeans, tomatoes, tobacco, chrysanthemums, gladiolus, and as soil treatment for vegetables.

4. DDT shall be permitted only for use on seedling cabbage, corn, cotton, peanuts, soybeans, and sweet potatoes.

5. Dieldrin shall be permitted only for use on peaches and sweet potatoes; as seed treatments; as soil treatment for fruit trees, turf; and as soil treatment for flower, foliage, fern, and woody ornamental s.

6. Endrin shall be permitted only for use on cotton, sugar cane, cucurbit seed, and pine seeds.

7. Heptachlor shall be permitted only as soil treatment for fruit trees, turf; and as soil treatment for flower, foliage, fern, and woody ornamentals.

8. Phosphorus (white or yellow) shall be permitted for use as a rodenticide by licensed pest control operators and governmental agencies only, for use in commercial and industrial establishments.

9. Sodium fluoroacetate (1080) shall be permitted for use as a rodenticide by licensed pest control operators and governmental agencies only.

10. Thallium sulfate shall be permitted for use as a rodenticide and for control of insects by governmental agencies only.

(c) Permit may be issued, for uses other than those stated in this regulation, to the following:

1. Governmental agencies engaged in control of pests and diseases affecting man, animals, and plants.

2. Governmental and private organizations engaged in research.

## TRAINING IN SURVEILLANCE

C. R. Grady 1/

In 1969 the North Carolina Forest Service received 2,142 reports of forest insect and disease damage. We assisted private and industry landowners with a total of 3,142 pest problems. A total of 2, 565, 600 acres were operationally surveyed to detect infestations of southern pine beetle. Most of the landowners assisted and all of the operational surveys were made by personnel who had not had instruction or experience in pest control work prior to employment with the Forest Service.

At this point, let me direct your attention to the map on the screen in order to acquaint you with the organizational structure of the N. C. Forest Service and to provide you with some background for my remarks to follow.

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1/ Staff Forester, Forest Pest Control, North Carolina Division of Forestry, Raleigh, North Carolina

The 100 counties of the state are grouped into 13 districts. The district is our Field Administrative Unit headed by a District Forester with a staff of one or two Forest Management Foresters, an Assistant District Forester and a Fire Control Specialist. In each county we have a non-professional man who is responsible for the forestry program in his county. Technical assistance is available to him through the District Staff and our Pest Control Foresters located in Morganton and Goldsboro. The County Ranger is our man on the ground and most of our training efforts are directed toward him and the district staff.

Our ground surveillance or detection network is composed of these county and district personnel plus 72 cooperators comprised primarily of industry foresters, tree service contractors, and other governmental agencies. These people report to us monthly any pest activity occurring in their work areas. Regularly scheduled aerial surveys are made to back up this network, With the foregoing as background, let me state that our training program is designed to achieve three major objectives.

The first objective is to acquaint our own people and our cooperator's personnel with existing and anticipated forest insect and disease problems to enable them to recognize and report the problems as they occur.

Secondly, we strive to give our personnel training to provide them with sufficient competency to give assistance to landowners encountering common insect problems. Here I want to emphasize the word "common", for I do not wish to imply that we are trying to make Pest Control Specialists of these people. The majority of our requests for assistance are of the commonplace variety that can be adequately serviced by a Forester with a basic knowledge of forest pests.

Our third training objective is to provide instruction on specific major problems as they occur. We train to meet our first objective, that of familiarizing our own personnel and cooperator's personnel with current and anticipated problems through regularly scheduled training sessions within the state. Presently the sessions are held biennially at five locations throughout the state. These sessions take the form of lecture and discussion type meetings, are one day in duration and are open to the public. Our own people comprise the bulk of the attendance, but we encourage participation by industry and other agencies with an interest in forest pest problems. At these sessions an attempt is made to give instruction in current pests that are posing a major threat to forest resources. We strive, also, to include instruction on anticipated problems. For example, two years ago the pesticide issue was just beginning to receive intensive public attention again. During that year's training

session we placed emphasis on instruction in regulation and safe use of pesticides. This year, with the gypsy moth active in Virginia we will include instruction on this insect. We receive invaluable assistance with the instruction at these sessions from the U. S. F. S. Division of Pest Control Staff in Asheville.

The second level of training takes the form of applied instruction in the field and is complimentary to the first level. Our county personnel, as I mentioned previously are sub-professional people. We upgrade the proficiency of these employees through in-service training that carries them through all phases of our program -- from Fire Control to Forest Management and including Pest Control. This program is administered in the districts by the District Forester's Staff. The Pest Control portion of the training involves instruction in identification of the more common forest insects and diseases occurring in the trainee's work area and control procedures for these pests. This training points toward our second objective of providing the Rangers with sufficient knowledge to give on the ground assistance under a Forester's direction. However, it serves to strengthen our surveillance network by reinforcing the instruction received at the biennial sessions. It also incorporates an important technique -- that of on the ground training. I cannot over emphasize the advantages of taking the training program into the woods and being able to show as well as tell.

Our Pest Control Staff fits into this phase of the program by compiling lesson plans and necessary training aids. We also work with the foresters administering the training when needed.

Our third level of training is initiated on specific problems as they occur. The need for this type of training arises when epidemics or situations of catastrophic or near catastrophic proportions exist. An example of this type training that readily comes to mind is for southern pine beetle detection and control. These training sessions are usually planned and administered by the Pest Control Staff. They are held within the areas experiencing difficulty and take the form of informal meetings in which trainees are acquainted with the nature of the causal agent, how to make identification, survey techniques, and control methods. This training is directed almost entirely toward our own personnel and is designed to prepare the district and county people for control efforts.

Now turning more specifically to the central theme of this workshop "A Look Ahead", I would like to mention just a few things which we as trainers might need to give attention to in the future.

To begin with I do not think any of us would deny that forestry in the South is moving along at an increasingly rapid pace. Intensive cultural practices are being installed to improve production on our existing forest base. In our own State we have recently initiated a forestation program designed to put back into production 20,000 acres of non-productive woodland per year. Forest pest problems will accrue from these practices as sure as God made little green apples.

Added emphasis is being given to the management of hardwoods. This management, with its attendant pest problems, coupled with the ever increasing shade tree assistance demanded by urban dwellers will require us to give attention to pests which we have not considered of economic importance in the past.

The trees that are in the ground now must supply the Nation's timber needs in the year 2,000 at which time we are told, the demand on our growing stock inventories will increase 77% for softwoods and 23% for hardwoods. Since this increase must be supplied from a decreasing forest base, forest owners will not be able to tolerate the losses to insects and diseases that have occurred in the past. More intensive protection for these trees will be required. What does this say to us as technical men and trainers?

Having worked for ten years in a strong fire control organization I subscribe to the old adage "an ounce of prevention is worth a pound of cure". I strongly feel that our training programs should place more emphasis on preventative measures and should vigorously attempt to influence forest managers to place proper emphasis on pest considerations in their land management practices. R. J. Kowal writing in the Forest Farmer states that "all too often top management pays little heed to advice of technical men until pest infestation reaches a point where expensive direct control measures are necessary". I feel that this situation exists partly because top management or decision makers are not made significantly aware of the consequences of ignoring insect and disease considerations in their land management decisions.

We already have some knowledge of the relationship of certain cultural practices and insect and disease incidence. The influence of vigorous stands, sanitation, and site disturbances, I think, are well enough known to provide us with some training material.

Other factors such as the effect of soil and site in predisposing a given species to attack is not well understood and we need information in this area.

Hardwood pests are another area in which we need more information and I am glad to see the U. S. Forest Service Division of Forest Pest Control recognized this need by placing a hardwood specialist on their staff.

Early detection and suppression are only slightly less important than prevention. Not enough can be said for detecting a pest outbreak while it is still small. Pest Control Trainers should be ever aware of potential threats and include these in their training programs to augment their detection efforts. Survey and detection techniques are being constantly developed and improved. We would do well to adopt and train in the use of the more promising of these.

I have briefly touched on but a few of the areas which we as trainers might need to consider in looking ahead. There are many others which time will not allow me to discuss; however, the fact is that forestry in the South is indeed changing -- intensive cultural practices with environmental changes will, without doubt, lead to an increase in pest problems. Quoting again from R. J. Kowal "we are admonished to adjust, train and learn to keep up with (the) change".

PANEL ON EVALUATION


Panel on Evaluation - L to R, R. J. Franklin, Professor of Entomology, University of Georgia, Athens, Ga.; W. H. Clerke, Entomologist, Zone 1, Asheville, N.C.; R. S. Forbes, Head, Forest Insect and Disease Survey, for the Maritimes Region, Fredericton, New Brunswick, Canada; C. F. Krebs (Moderator), Biometrician, Area Office, Forest Pest Control, not in photo.

# PEST DETECTION AND APPRAISAL IN THE MARITIMES REGION OF CANADA

R. S. Forbes 1/

First of all I want to say that it is a pleasure and a privilege for me to be here today --a pleasure because of the opportunity to meet new friends and to say something of Forest Insect and Disease Survey work in eastern Canada -- and a privilege because of the chance to learn of your problems and how you are handling them. I feel sure before the hour is up that many of you will be convinced that the air that comes from Canada is not always cold.

This is my first visit to this area and my knowledge of conditions is indeed scanty. There are, of course, many environmental differences between Georgia and my native Province of New Brunswick, many associated with a difference of about 15$^{\circ}$ of latitude. Some of these differences are profound. For example, Georgia has, I believe negligible amounts of snowfall; whereas New Brunswick has a mean annual snowfall of about 100 inches. Georgia has a mean of 259 frost-free days as against 102 in New Brunswick. Georgia has forests characterized by oaks and pines whereas New Brunswick's consist mostly of spruces, balsam fir, maples, birches, aspens and beech. There are some similarities however, that are rather striking. Both have coastal climatic influences, both have a high proportion of their forested land under state and private ownership, both have pulpwood as a prime industry, both have the dubious honour of sharing the presence of such pests as the fall webworm, fall cankerworm, forest tent caterpillar, Dutch elm disease, and white pine blister rust, and both areas are exerting every effort possible to manage their forest resources and the pests in them.

This brings me to the subject of the moment -- the detection and evaluation of forest pests and their damage in Canada, and more especially in the Maritime Provinces of New Brunswick, Nova Scotia, and Prince Edward Island. Such work in Canada is conducted by a national project called the Forest Insect and Disease Survey, which operates within the Canadian Forestry Service of the Department of Fisheries and Forestry. The Canadian Forestry Service -- which undertakes a broad forestry research program -- operates under the direction of an Assistant Deputy Minister assisted by senior advisory, operational, and program coordination directorates in Ottawa, seven regional research laboratories, and eight research institutes (Chart 1). The budget for the Canadian

1/ Head, Forest Insect and Disease Survey, Maritimes Region, Department of Fisheries and Forestry, Fredericton, New Brunswick

Forestry Service in 1970-71 is about $23 million. Each of the seven regional laboratories under the direction of a regional director and associate regional director, has a forest protection program -- consisting of sections on forest entomology, forest pathology, forest insect and disease survey and forest fire research -- and a forest resources program made up of sections on silviculture, tree biology, and soils and sites. Units of forest economics and management and liaison services are also included. The regional laboratories are at St. John's, Newfoundland; Fredericton, New Brunswick; Sillery, Quebec; Sault Ste. Marie, Ontario; Winnipeg, Manitoba; Calgary, Alberta; and Victoria, British Columbia. At present there is a move to amalgamate work done in the prairie provinces and the North West Territories. This means that the Winnipeg Laboratory would be phased out and Calgary would become headquarters for such work.

Thus as indicated above, there is a unit of the Forest Insect and Disease Survey at each Regional Laboratory. What then is this Forest Insect and Disease Survey? How is it organized? What are its objectives and functions? What are its main accomplishments? These are some of the questions I hope to deal with this morning.

The forest insect part of the Survey was organized in 1936 to meet a growing need for information and extension services. Its origin was closely related to the severe European spruce sawfly outbreak in eastern Canada, and therefore the Maritime Provinces was one of the first regions in which the Survey was organized. Its principal objective at that time was to determine the distribution and severity of European spruce sawfly infestations and to collect and study other insects on spruce. Following World War II the Forest Disease Survey was organized, but it was not until 1964 that these two surveys were integrated.

The original objectives have, of course, been broadened considerably and now may be stated as follows:

1. To determine the status of all forest pests and to forecast, locate and define the distribution and intensity of outbreaks and infections and report the information through suitable channels.

2. To obtain all possible information on the identity, distribution, biology, natural control agents, and general ecological relationships of forest insects and tree diseases.

3. To provide advice to agencies and individuals concerned with the localized control of forest pests.

All sub-project research work by professionals associated with the Survey is closely geared to these objectives.

Now these objectives are generalized and so one can find little fault with them. They seem to fit our program today as they did ten or even twenty years ago. However, to keep pace with demands from provincial and industrial agencies, national parks, and individuals, for more and better detection and appraisal coverage and improved extension services, we are taking a close look at these objectives and at our present organization. We are asking ourselves if our program meets present needs of industry and provincial forest services. We are asking ourselves if it is organized to meet these needs. We are asking ourselves if our results are meaningful to forest protection agencies and if we can improve on their translation, communication, and utilization.

In 1968 the Survey assumed responsibility for evaluating the immediate results of spraying operations in New Brunswick in terms of population reduction and protection to foliage, and for conducting all regional aerial and ground surveys of spruce budworm incidence and damage. This work has been conducted by a separate aerial spray project since the inception of aerial spraying in New Brunswick in 1952.

At this point I might say that the organization and functions of each survey unit across Canada are basically the same but there are, of course, differences in assignments and procedures related to variations in forest conditions and pest problems.

In the Maritimes Region, there are 20 persons associated with the Survey, five of whom are Research Officers (Chart 2). We have seven field districts each covered by a district ranger (Chart 3). These rangers and all aspects of operational field work are supervised by a Chief Ranger. The Chief Ranger reports directly to the regional Survey Head.

All functions associated with the above-mentioned objectives -- field or laboratory, entomological or pathological -- are integrated through the preparation each year of a detailed work program which in effect gives the what, where, when, how, and to some extent the why. This is our work "Bible"!

## DETECTION AND APPRAISAL

### General observations

The objectives for the detection aspects of the Survey are pursued through general observations and sampling by the seven field technicians and by

cooperating personnel of provincial and industrial agencies, especially the New Brunswick Department of Natural Resources and the Nova Scotia Department of Lands and Forests. These two provincial organizations each provide 45 of their rangers -- one from each of their ranger districts -- who are interested in the biological aspects of forest protection. We conduct periodic training sessions for these personnel on observing pest damage and taking collections. This sort of cooperation is now considered an integral part of their forest service duties. Thus, we have 90 additional pairs of trained eyes to spot and report on things they consider abnormal or unusual in the forests, i. e. weakened or dying trees, crown dieback, or defoliation. All such reports are checked by Survey field staff and the co-operator is informed of the causal organism or factor involved. In recent years Survey staff have made increased use of aircraft, and aerial observations are now considered indispensable in many cases to the full and accurate recording of conditions. About 75 hours of chartered flying time were used in 1969 and I expect 100 hours for 1970. Each of our rangers prepares flight plans to cover his district once during June, July, and August at intervals of no more than three weeks. Conditions spotted and mapped are then checked from the ground.

Sampling

'The tree beating method', used almost since the inception of the Survey, is the basic technique for sampling larval defoliators of conifers in the Maritimes Region. It involves jarring all branches on one side of the tree with a 10-foot pole so that immature insects are dislodged and fall on a 7- by 9-foot canvas sheet placed under the canopy of the tree. The insects are placed in a container with relevant data on time, place, host tree, forest type, etc., and forwarded to the Forest Research Laboratory, Fredericton for identification, counting and rearing.

The basic sampling unit is three trees. Density is expressed in terms of numbers of individuals per tree sample. This method of sampling has many shortcomings including its restricted use to relatively young, open-grown trees with branches on the lower portions of the stem.

Three types of beating samples are taken annually to assess abundance of forest defoliators:

- -- from permanent sampling areas
- -- from areas selected at random, and
- -- samples collected by co-operators in areas preselected by F. I. D. S. technicians.

Permanent Sampling Areas - These areas, totaling 170 in the Maritimes, include stands of one or several tree species representing the main forest types in the region. The areas are numbered and the location, history, and description of the stand are recorded. Such areas are selected:

-- to provide an annual measure of the abundance of a number of insect species
-- to obtain specimens of fauna in the main forest types in each ranger district
-- to obtain information for particular species on parasitism and other agents of natural control.

The sampling procedure consists of beating three trees of each species one or more times per season. This method, crude but practical, and ideal for the use of co-operators, provides broad population trends. An example is seen in the build-up of populations of the spruce budworm in New Brunswick in the late 1940's, which led to peak population densities in 1952 and since then to the longest and most severe insect outbreak ever seen in New Brunswick.

| Larvae per tree sample | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 |
|---|---|---|---|---|---|---|
| | 0.3 | 0.4 | 0.8 | 1.5 | 1.7 | 6.4 |

However, it was only recently in comparing spruce budworm larval sampling records by the Survey in northern New Brunswick with intensive independent sampling results at our Green River field station that the accuracy of the Survey tree beating method could be assessed. Chart No. 4 shows that the general level of population abundance as measured by the F.I.D.S. is relatively consistent with estimates from intensive sampling in the Green River area, and that the trend in density, with three exceptions, is relatively consistent. Even though the comparison is between one watershed and the whole of northern New Brunswick, it is apparent that the Survey sampling technique provided a reliable measure of budworm population trends in northern New Brunswick during the period 1957 - 1967.

Similarly, recent comparisons of Survey sampling records of the European spruce sawfly in New Brunswick with those on two plots in the central part of the Province over a 32 year period show that the method is an effective monitoring tool. Chart No. 5 indicates populations fluctuated at generally low levels during this time.

Random sampling - This type of sampling is considered basic to a good program of surveillance and detection, and follows the tree-beating procedure outlined above. The number of locations sampled varies from year to year and is largely dependent upon changing forest condition and the astuteness of the ranger involved.

Co-operators sampling areas - There are 45 such areas in New Brunswick (and as mentioned above, 45 in Nova Scotia), one for each provincial co-operator. In each location there are at least 18 white or red spruce trees, 18 balsam fir, and 18 of one other species common in the area. Three spruce, 3 balsam fir, and 3 trees of the third species selected are sampled by the beating method twice a month during June, July, and August. Thus each co-operator is asked to take 3 samples twice a month or 18 for the season. To insure that all collections are not taken in one period of time, one-half the provincial staff appointed to collect insects takes collections during the first and third weeks of each month and the remainder during the second and fourth weeks. Each sampled tree is marked with colored tape, so that the same trees are not sampled twice in one summer.

Despite the above results indicating that the tree-beating method is good for general sampling, there may be a better one. In 1969, consideration was given to the adoption of the uniform larval sampling technique in each region of eastern Canada. Trials were made of a method used in Ontario. Basically the method consists of 2 beating samples from each of 10 trees over a 1-square yard tray, with a pole 1-yard long. One cubic yard is therefore the sampling unit and 20 of these are sampled at each station. A check of the results using this method and that described above is presently underway.

Other sampling techniques are used in permanent sampling areas where insects are counted on units of foliage, e.g. larch casebearer, winter moth. We have about 60 sampling areas of this type.

Phenological differences of considerable magnitude occur in various parts of the Maritime provinces, due to climatic and weather patterns associated with both coastal and inland environments. In recent years efforts were made to determine these differences in seasonal development, considered basic to adequate planning of seasonal work programs or sampling schedules. Accordingly, a phenocontour map was prepared, based primarily on shoot-growth measurements of balsam fir over a 6-year period (see Morris, Webb, and Bennett, Can. Jour. Zool. 34: 533-540, 1956) (Chart 6)

As for forest diseases, the concept of representative sampling areas and sampling intervals is presently being introduced and tested. For example, study is underway of comparison of plot size to determine accuracy of sampling results for white pine blister rust. Also, a technique is being tested to follow the yearly fluctuation of the level of needle rust infection based on the number of infected needles per centimeter of branch.

Damage appraisal

According to a report of the National Forestry Conference in 1966 the demand for Canadian forest products will increase five-fold by the year 2000. Canada will go from an era of wood surplus to one of wood scarcity. Research will thus be aimed towards increased productivity by increasing growth of forests and reducing current losses. Heretofore the resource appeared limitless and social attitudes (i. e. conservation, regulations on private land, etc. ) have been tuned accordingly. Thus to be practiced are not only measures of forest management but also those of social management.

It is said that losses from insects and diseases in Canada are in excess of 1. 0 billion cubic feet of merchantable timber annually (and from fire another 0. 5 billion cubic feet). However, no reliable estimates of losses are available on which to base management decisions and to justify expenditures for research effort or control measures. Some information on forest losses is available, but it is fragmentary and available for only parts of the country. Moreover, it tends to centre upon one loss-causing agency and is not in standardized form.

A multi-disciplinary committee has been formed, however, to review the current situation and see what should be done to obtain reliable and useful estimates of forest losses. The deliberations of this committee point up: (a) the inadequacy and nature and scope of present loss estimates; (b) the need for standardization estimates permitting re-compilation into national figures; (c) the need to consider the impact of more than just one loss-causing agency (combining separate surveys could lead to misleading and conflicting results);(d) the value of provincial forest inventory data, even though some provinces used different standards, procedures, and timing; (e) the need for definitive objectives, sub-objectives, goals, and aims, to determine accuracy required; (f) the need for a valid economic appraisal of the loss. For example, value is a function of time, place, and form - a cubic foot of pine does not have the same value today as in 1900, nor the same value on the stump as in the mill-yard, nor the same value in a 16-inch log as in a 6-inch log.

Also, it is often assumed that volume destroyed could be sold at current prices whereas flooding of markets with large volumes of timber might drastically decrease the market price.

Further, the committee suggests that the ideal would be to combine surveys of losses with a fully standardized national forest inventory. Loss statistics don't mean much without knowing the values from which these must be subtracted, and these values would be provided by such an inventory. The committee urges that a federal unit be made responsible for compiling loss statistics, whether or not these are combined with a national inventory. This unit should have experts in forest mensuration, statistics, economics, silviculture, entomology, pathology, and physiology. This group would have access to all provincial forest inventory data and the capability to collect data where gaps exist. No doubt the Forest Insect and Disease Survey would appear "on stage" at this point.

But in the meantime while these plans are still on the "drawing board" what can and should be done? The answer may be largely intuitive or depend on problems or program emphasis in regions. At present each region is asking itself the following questions, answers to which will help in future decisions in estimating losses and standardizing procedures. Our program coordination group is presently spearheading this effort.

1. What pests cause significant damage to forest trees in a region?
2. What techniques are used to classify infestations or infections?
3. How much variation exists in these techniques and can they be standardized?
4. What information is now available on the use of these techniques and the results?
5. Is any information available from provincial inventory data (e. g. decay losses)?

In the Maritimes the most significant progress, made by our Forest Disease Survey group, is summarized below:

1. Preparation and issuance of a "Field Manual of Tree Diseases in the Maritimes Region". This has helped provincial and industrial field staffs recognize forest diseases and their damage.

2. During recent in-service training programs, differences were stressed between annual and perennial diseases, and impact studies were planned to cover one or a group of these perennial diseases each year.

3. In 1967 emphasis was given to occurrence and impact studies of white pine blister rust, eastern dwarf mistletoe, and armillaria root rot, in 1968 to Hypoxylon canker of poplar, sweetfern blister rust, and in 1969 to beech bark disease and globose gall rust on jack and Scots pine. The results from these surveys are outlined in our annual Survey reports for 1967, 1968, and 1969. Similar surveys on these agents will not be conducted for at least 5 years.

These results, although rough, suggest the nature and extent of damage by these agents and help show defects and shortcomings in techniques. More especially, however, they suggest directions of approach for future programs. For instance, a need is shown for photosynthesis-respiration studies for some agents -- that is, what effect on the tree is caused by 20% defoliation for 2 years? Also, stocking is not considered in provincial inventories and often receives little attention in assesing losses. For example, if a stand consisting of beech, sugar maple, and yellow birch has the beech entirely destroyed, and yet the remainder of the stand is adequately stocked with sugar maple and white birch, what does the loss really amount to?

## Prediction

In recent years increased emphasis has been placed on techniques forecasting the status of important pests. For example, the sampling of spruce budworm egg masses at some 1,200 locations in New Brunswick each August provides expectations of the degree and extent of infestations the following year and helps greatly in the planning of spray operations and budgeting of funds.

In 1969 we made our first big splurge into this area (with fingers duly crossed). The returns from a questionnaire circulated in late 1968 to about 300 recipients of the Seasonal Summary Report of the Survey indicated that a brief pre-season forecast of the status in 1969 of some important pests would be of value. Accordingly, records were analyzed and field data obtained to throw some light on insect conditions expected in 1969. It was felt that realistic predictions of the status of many tree diseases were not possible because of the complex interactions of host, fungus, and weather. We were careful to point out that predictions of the status of insects, based on counts made late in 1968 or on overwintering populations, could be quite invalid as they do not take into account the possible effects of winter weather conditions, parasites, diseases, etc. We reasoned that even if some agencies and operators or owners of high-value trees could be alerted in time to consider measures of control then this preview of conditions would be well worth while. Indeed,

it was well received. Most of the forecasts held true but we did make a few "boobs" which proved to be due to some areas either being not covered or not covered intensively enough during egg sampling.

Light traps - Light traps have been operated for a number of years by co-operating field staff in New Brunswick and Nova Scotia under the guidance of our field staff. At first they were operated at fire towers with Coleman lights and recently at provincial ranger headquarters locations with black light. We operate 17 in New Brunswick and 2 in Nova Scotia.

At present the records from these traps, covering a 6-year period, are being analyzed and a report will be prepared, hopefully this winter. It is apparent, however, that the results show periods of moth activities, occurrence of mass flights, and changes in abundance from year to year. There are also two or three outstanding examples where light trap data have helped to locate and predict outbreaks of forest insects. I realize there are many variables that can have a significant effect on the results obtained, such as weather, stand type, topography, etc. Our report may shed further light on the usefulness of light traps and on their potential as another Survey sampling tool.

## IDENTIFICATION AND SPECIAL REARING

The objectives for identification and biological studies are followed by an insectary rearing program closely integrated with the field aspects by means of a detailed work program, as mentioned earlier.

A hard look is to be given our present insectary rearing program. For many years an extensive program of rearing was carried on to get adults for confirmation of identification and to get information on parasites and diseases. Much data have been accumulated. Some have been published, expecially in compilations like "Forest Lepidoptera of Canada" (Volumes 1-4), and more will appear in another compilation now underway on hymenopterous parasites of forest lepidoptera. Many of these records are on magnetic tape and readily available as print-outs. They provide information useful in forming decisions on biological and chemical control and which is often meaningful to research staff. Granted, we haven't identified or reared all the insects in our ecosystem (and we never shall) but we feel the time has come to make changes in our rearing approach. In 1970, instead of trying to rear thousands of specimens of several dozens of species (for a questionable amount of new or significant information and a great amount of effort spread thinly), we shall concentrate on perhaps six "high priority" species. If objectives can be satisfied in

2 or 3 years, the results will be reported on or published and other species or species groups selected for study. All material received from the field -- some 4, 500 insect collections a year -- will be identified as in the past and basic collecting data will as usual go into the data-processing "bank". Reasons for rearing miscellaneous material, however, must now be very compelling.

## Recording

As the Survey broadened its objectives, added more staff, and improved its programs of sampling, identification, and rearing, better recording practices became necessary to keep pace with the necessary filing, indexing, and analysis of data. From 1936 to 1950 field data was recorded on very simplified enclosure slips and all incoming material of the same species was group reared by county. Thus, there was no way to single out rearing information about one specific collection (unless, of course, there was only one collection in one county). In 1951 a new enclosure slip heralded the advent of Remington-Rand Punch Cards and the use of a punch machine, verifier, and sorter from 1952 to the end of 1966. The adoption of this system, characterized by having all collecting and some rearing information of each species in each collection punched on a separate card, proved to be a "giant step forward". But this system had its shortcomings (e. g. there was no easy way to process sampling data). In 1967, a much more advanced enclosure slip was designed to accommodate both field data and laboratory identification for both insects and diseases. This new sampling form, designed as a field record sheet and a source document for machine punching, accommodates standardized codes and classifications compatible with other disciplines and data processing activities of the Department. In other words, the F. I. D. S. sampling form lends itself to the recording and extracting of data in other forestry disciplines besides pest surveys. All observations and collections are now so recorded, and in turn processed onto magnetic tape in Ottawa. Machine print-outs for data in various combinations can be obtained within a few days on request. Ultimately, species distribution maps will be provided through this system. All back data on Remington-Rand Punch Cards have now been transferred to tape (on I. B. M. format).

# LIAISON AND EXTENSION

## Liaison

Industry - As with the provinces, a good program of liaison and communication has been established with industrial agencies. Beginning in 1964, each major corporation was urged to select someone in each of their main

divisions with whom periodic contacts could be made by our field staff during the summer months. It was envisaged that such an appointment would not entail much time and would not require a detailed knowledge of insects or disease organisms or their damage. It was suggested, however, that each representative appointed might sometimes be able to accompany our ranger during his sampling or observational visits to company divisional limits. In this way, it was hoped that the company representative would gradually become familiar with the more common and important pests and their damage. This arrangement has worked well and has provided for considerable interchange of knowledge regarding forest pests between Survey and company staffs. This, of course, is beneficial to company interests and ultimately will provide for more effective surveys of pest conditions. Requests from company foresters for short courses on the recognition of important pests and their damage are now common, and each year we conduct several.

In 1969, in an effort to make our Surveys and reporting more meaningful, we requested from one of the larger pulp and paper companies detailed maps of their limits. The idea was that we could sketch the nature and extent of infestations or infections on overlays of these maps and send these to the management foresters. This would provide them with an up-to-date picture of pest conditions in their own "backyard". It was felt that such a step would place them in position to early consider matters relating to management or control. It is too soon to assess the value of this practice but the potential seems great.

National Parks - Periodic contacts are made with Parks personnel. Here again, training sessions are held every year or so. Special reports on pest conditions within the Parks are issued each year. In the case of serious outbreaks, special appraisal surveys are conducted and reported on promptly.

Extension Services - Most liaison here is in connection with pests in small woodlots and more especially on balsam fir and pine trees grown for the Christmas market. Recently, we issued a manual on Christmas tree pests that proved to be a "best seller". In fact it was so popular that we intend to beef it up with color prints, reduce it to hip-pocket size, and issue it as a departmental publication in 1970.

Talks by Survey staff (with color slides) on the recognition, damage, and control of pest organisms to associations of woodlot owners and Christmas tree growers are being requested more frequently each year.

Major Cities and Towns - Our Tree Pest Extension Officer advises responsible officials of major cities and towns on pest control problems. Many of these contacts to date have been concerned with Dutch elm disease. We have tried to encourage the appointment of a liaison or contact man (town clerk, town manager, works engineer, park superintendent etc.) in each major town or city through whom reports of disease incidence or recommendations for sanitation and spraying can be directed. From this we see that such appointees, with similar liaison individuals appointed by the provinces, would be key persons to whom all pertinent literature, reports, and recommendations could be sent and with whom meetings, either on an individual basis or collectively, could be held. This program has been reasonably successful.

Extension

Extension inquiries from forestry and municipal agencies and individuals have tripled in the last 4 or 5 years, reaching 644 in 1969. The work load in this program is greatly facilitated during the busy period through the distribution of illustrated leaflets outlining the background, life-history, and control of important pests. We feel that the information and illustrations in these leaflets and in others to be prepared will form an integral part of a manual on the control of shade and ornamental tree pests planned within the next 2 or 3 years.

## DISSEMINATION OF INFORMATION

At present we are taking a close look at this part of our program in the light of current austerity measures, and the degree of duplication involved. There is no question but that the Survey has a basic commitment to communicate information leading to early control of pests and their damage. Through the issuance of seasonal and annual and special reports, our forestry community is kept well informed of the status of important pests but sometimes I wonder if we are overdoing it! Are we reporting ourselves to death? How much of it is in meaningful down-to-earth form? How much of it is duplicative? Is it too detailed for the general reader? Some of these questions stem from the fact that we prepared 19 reports in 1969 dealing with a variety of problems and a variety of agencies.

I believe this is a basic problem. If we are to make the best use of the time and man-power at our disposal in the planning and execution of pest detection and appraisal, research, and extension and control, we must achieve a balance in our reporting schedules which, because of the wide variety of problems and interests involved, is not always easy to find.

## RESEARCH

Apart from the activities outlined above, professional staff of the Survey conduct research studies directed toward fulfilling Survey objectives. In the past 5 years results of these studies have been incorporated in 20 contributions in scientific journals and departmental publications.

I believe that any elaboration by me at this time of the kind and amount of research conducted by Survey officers would over-extend my time and would be outside the scope of this presentation. The present research programs are simply listed below to show where emphasis is being placed:

## FOREST INSECT AND DISEASE SURVEY

1. Detection and damage appraisal of forest diseases.
2. Pruning wounds on balsam fir as infection courts for decay-causing organisms.
3. A tree condition survey near the belledune smelter.
4. Biotaxonomic studies of forest fungi.
5. Comparison of *Polyporus abietinus* on balsam fir from the Maritimes and Ontario.
6. Separation of some closely related species of *Polyporus* in culture.
7. Biological assessment of aerial spraying against, and status of the spruce budworm.
8. Tree pest extension program in the Maritimes region.
9. Spring phenology of the Maritime provinces.
10. Taxonomy and bionomics of forest Homoptera: Adelgidae, Coccidae and Margarodidae.
11. Bionomics of *Neodiprion virginianus* complex on jack pine at Bartibog River, New Brunswick.

## "A LOOK AHEAD"

The theme of this meeting is "A Look Ahead". But to see clearly where we are going often requires that we look back and see exactly where we have been. We must assess both our accomplishments and our weaknesses. In retrospect, the Survey has played a valuable role in monitoring fluctuations of pest populations, in the early recognition or identification of important pests and their damage, in research, and in extension and liaison. We lack good sampling techniques and we are spreading our efforts much too thinly. We have made lots of mistakes and we shall make more but we must profit by them. Our progress in the future will be limited only by our imagination and our energy. There is much to learn and many improvements to make. Let's hope we can meet the challenge! In any case, it will be fun trying!

# SOUTHERN PINE BEETLE POPULATION BEHAVIOR

Rudolph T. Franklin [1/]

The purpose of this study was to determine the responses of the southern pine beetle, Dendroctonus frontalis Zimm. (Coleoptera:Scolytidae), in a natural infestation.

Infestations of the southern pine beetle are discontinuous. Initial infestations apparently occur at random in piedmont shortleaf and loblolly pine stands, or, often are associated with lightning struck trees. Endemically, these infestations may consist of from one to several hundred trees, usually 1-15 with an average of 30 to 150 infested trees per 1000 acres of host type. On first consideration such low incidence of attack might seem unimportant, however, as this report will indicate a small beetle population, especially in the spring of the year, may have a significant impact upon a forest stand during the course of one season.

The southern pine beetle has several generations per year. The female beetles attack a tree first and release a pheromone as they bore into the bark. The pheromone and host odors draw the available beetle population to the tree (Gara, 1967). If the attack is successful, the beetles excavate serpentine galleries in the inner bark killing the tree. If the tree is in a vigorous condition the initially attacking beetles may be "pitched out" and the attack will not be successful. Trees successfully attacked are killed. Eggs are laid on each side of the gallery, with the larvae feeding and developing in the inner bark. The new beetles leave the bark through their own individual holes, flying and responding to attractive sources immediately (Tsao 1966).

The key to a successful southern pine beetle infestation is the production of an aggregating pheromone by the female beetles when they first attack a tree. The pheromone concentrates the available population so that in concert the beetles are able to successfully overcome a tree.

## METHODS

This study was conducted on the School of Forest Resources, University of Georgia forest, in Clarke County during 1967 and 1968. The stand was a 30 year old mixed pine-hardwood consisting primarily of shortleaf pine, Pinus echinata Mill., and several species of oaks and hickories.

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The 670 acre forest is surrounded by old fields and pastures. The 4.5 acre study area was relatively isolated, being on the corner of the forest with old fields on two sides and a clear-cut area on most of another side.

The southern pine beetles were attracted by using fresh pine bolts, in which female beetles had been introduced. The method was similar to that of McCambridge (1967) for the Black Hills beetle. The introduction was done by drilling 5/32" holes 1/2" deep into the inner bark through the cut ends. The bolt was caged overnight with 150 female beetles. The holes facilitated the entrance of the beetles into the bark. As the study progressed we found that we did not need to sex the beetles. The newly infested bolt then was removed to the forest and attached to an appropriate apparently healthy tree in the research area.

A study unit consisted of a newly infested pine bolt attached to a tree at approximately 6 feet above the ground. A square foot 16 x 18 mesh wire screen, 6" x 24", coated with Stikem Special was attached to the tree on the side opposite the bolt. Beetles responding to the attractive source were caught on the screen. The number of beetles becoming trapped gave a relative indication of the activity of the beetles on the tree. Obviously only a small percentage of the beetles responding were trapped. A square foot area, 6" x 24", was marked on the bark of the study tree. The number of emergence holes counted in this area each day gave the emergence per square foot of bark and the timing of beetle emergence. If beetles did not respond to the study unit the infested bolts were replaced every two days until natural attack did occur. Study units were set up one at a time during the early part of the season, depending principally upon the availability of beetles both for infestation of attractive bolts in the laboratory, and for response to the trees in the forest.

There was one naturally infested tree in the study area on April 14, 1967. A careful search for infested trees indicated that this was the only infested tree within a significant distance in the forest. We were confident, therefore, that we knew where the southern pine beetle population was and which beetles were responding.

## RESULTS

Figure 1 maps the pattern of responses and attacks described in the following paragraphs.

On April 21, in response to bolts with female beetles, attacks were successfully induced in two trees 2 meters apart and approximately 5 meters from the original tree. On April 27 another tree was attacked, another on May 1, and another on May 8. Beetles continued to be active in this spot until May 19. Ten trees attacked in all.

The next attempt at starting an infestation was at a point approximately 40 meters from the first. Fresh bolts were used for nearly two weeks before the first beetles were attracted. Once attraction was established, on June 9, attack continued for 20 days. These attacks coincided with beetle emergence from the original infestation. A total of 12 trees was infested. During this attack period beetles were also led to another spot 20 meters away where seven trees were infested.

On June 20 two bolts each, with females only, males only, and with both sexes were tried. The response was dramatic. Five trees were attacked within hours, one tree with male beetles was attacked the next day, and an additional 13 trees were attacked during the next 15 days. Bolts with unsexed beetles were used in the remainder of the study. From here beetles were then attracted back to the original spot on July 1. Eleven trees were infested during a ten day period of activity.

At this point in the season natural infestations started occurring independently and with dramatic effect. During the latter part of July and through August, apparently by sheer weight of numbers of beetles, tree infestations started occurring continuously and in large numbers. Even two inch saplings were being attacked and killed. On July 30 infestations were induced on three trees against the direction of movement of the spot, but in terms of the total number of new infestations occurring these could not be considered significant.

The natural attacks and infestations started to subside in September as the weather began to cool. A number of infestations were induced during September and October. The last successful infestation of the season, an induced attack, occurred on November 11.

From one infested tree in April, 187 trees were dead in November. Although some pines remained in the area, especially where the beetles had not yet reached, the stand had essentially been converted to a hardwood stand.

Except for the break in late May and early June southern pine beetles were trapped on some screens every day of the season. Even during the winter months that followed, beetles were trapped on most warm days (60 F +) although successful infestation did not occur. During the summer no tree survived an induced attack.

The usual pattern of attack, during the summer months, consisted of a few beetles arriving at the tree shortly after the attractive source was placed (Fig. 2). The next day 10 to 30 beetles might be trapped on the screen. On the third or sometimes the fourth day the "mass attack" occurred. Over 100 beetles often were trapped on the screen. The attraction of beetles then dropped off just as rapidly as it began. Apparently beetles are diverted to other trees. After one week from the time the attack began no more beetles came to the infested tree.

In approximately two weeks the significant and formerly unrecognized emergence pattern of the beetles from an infested tree begins. There are two distinct peaks of emergence. The first emergence starts to occur in from 13 to 15 days after the initial attack and continues for about 10 days. This is before the brood has had time to complete development. This emergence consists of the beetles (parent beetles) which initially attacked the tree. In approximately 40 days from the original attack the new generation of beetles (brood beetles) start to emerge. This emergence period lasted 20 days or more, with a few stragglers coming out much later.

## DISCUSSION

The initial induced infestation in the stand consisted of two trees and a total of ten trees was infested during the three week period. The last trees attacked apparently were infested by parent beetles from the original two trees, since these attacks coincided with emergence from the original two. Attacks then stopped, apparently through lack of available beetles. This caused a break in pheromone production. A few emergences occurred during this period but with no available attractive sources the beetles were apparently lost through dispersal.

The next induced infestation (June 9) coincided with brood beetles emerging from the original infestation. From this point in the season additional infestations were easily produced using attractive sources, until by late July the total number of beetles available was so great that natural infestations far exceeded induced infestations. By August new infestations were occurring at an exponential rate.

The critical point in the southern pine beetle life history, apparently unrecognized in the literature, is the emergence of parent beetles and the later emergence of brood beetles from the same tree. The significance is twofold with the key being the production of aggregating pheromone. With two emergence periods, and the ensuing two attack periods, the aggregating pheromone is produced at two intervals, rather than one, in the life history. If there were no reemergence of parent beetles there would be a 30 day period before the emergence of new beetles. In this interval sources would long since have lost their attractiveness and the chance of successful aggregation of the new brood would be greatly lessened.

The second significance of the two emergence periods becomes apparent if we can assume that the parent beetles are able to successfully infest another tree and that the brood beetles are able to attack at least two additional trees. The potential for population increase is fourfold rather than twofold since each group of parent beetles, through reemergence potentially can produce enough brood to overcome four additional trees. Since there is also an approximately 14 day delay until the second infestation of reemerged parent beetles there should be a corresponding delay in the second brood emergence. This caused overlapping emergence and the ensuing new attacks, assure that there will be aggregating pheromone in constant production to orient the newly emerging beetles.

An additional significance of the overlapping emergence pattern is the futility of counting the number of generations per year (Fig. 3). Assuming one generation takes approximately 40 days, in 160 days there should be four generations. With parent beetle reemergence and attack there are 16 individual generations. The number (in parenthesis) indicating additional generations by the same parents, show that different generations may actually overlap. A third generation may occur at exactly the same time as a fourth generation.

The numerical subscript to the tree symbols, indicating the number of trees attacked, shows the potential for population increase under the multiple generation concept. Instead of 16 trees infested at the end of 160 days, in a 40 day generation mode, there are 208 trees in the projected infestation. The actual forest infestation in the study substantiates this projection.

Speculation upon the progress of a hypothetical infestation is now possible (Fig. 4). Assume the first new attack of the season occurs March 15 (supported by actual forest data) by brood from one infested tree. These beetles reemerge and attack another tree and the brood produced in each of these trees attack two additional trees, as in Fig. 3. After the attack the tree is counted as infested for 40 days and dead.

The critical stage for the population occurs in the early part of the season. There are few trees being attacked and rather long intervals between attacks. At this stage any upset of the delicate balance could be disasterous. For example, an extended rain storm might effectively flush the pheromone out of the stand and cause the beetles to become disoriented and disperse. By late June and early July new attacks are occurring continuously and the population is in rapid growth.

The population growth does not start to slow until the temperatures in late September and early October start dropping below the 58 F level in the evenings. From this point on new infestations occur but at decreasing rates. Finally the last successful attack was on November 4 (forest data). The number of trees infested continues to drop because daytime air temperatures are usually well above the threshold necessary for emergence and flight. However, apparently the cooler evening temperatures prevent the beetles from successfully establishing themselves on the trees. Beetles continue to emerge and fly all through the winter whenever there is a warm day. This included most days in November, 25% of the days in December and January, 50% of the days in February. By early March the number of infested trees from the previous season is down to very nearly the one tree of the preceeding March.

This projection of a hypothetical population gives some insight into the management of a southern pine beetle population. First the potential for increase is spectacular. However, there are some tactics indicated. Early spring and summer control can break the emergence and pheromone production patterns because fewer beetles are present and there are longer intervals between attacks. Attempts at control during the summer will fail. Figure 4 shows that anytime during the summer half of the population is flying and attacking additional trees. Thus a complete treatment of all infested trees will get only half of the population.

At least in the latitude of Athens, Georgia a mild winter is more detrimental to the beetle population than a cold one. Temperature ranges from perhaps 25 F at night to 75 F in mid-afternoon of the same day may occur anytime during the winter. Brood development occurs all winter long. The beetles are able to fly anytime upon warming (apparently about 58 F). Thus at the warm part of the day the beetles are able to emerge and fly. However, with rapid falling of temperature in the late afternoon and evening the beetles apparently are unable to successfully find another tree. Most of the population is lost during the winter without any direct control action.

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Figure 1. Pattern of southern pine beetle infestation during the season 1967-68, Clarke Co., Georgia. One naturally infested tree present April 14. Triangles show trees in which attacks were induced. Dots indicate additional trees infested. Roads border the area.

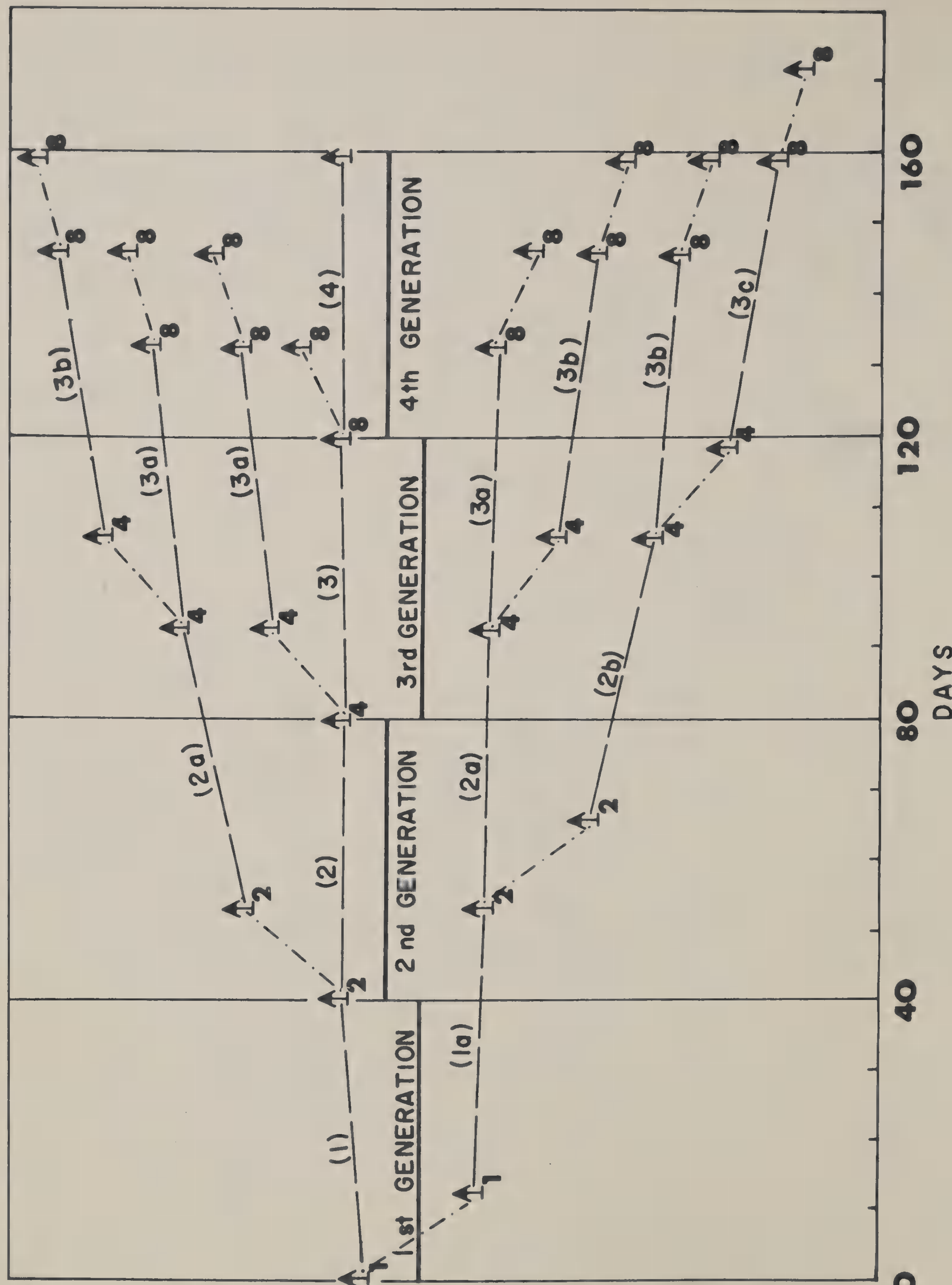


Figure 3. Hypothetical portrayal of the development of southern pine beetle generations assuming 14 days for parent beetles to reemerge and 40 days for the brood beetles to emerge. Numbers and letters in parenthesis indicate each generation with its excessory generations. Subscript numeral with tree symbol indicates the number of trees attacked and infested.

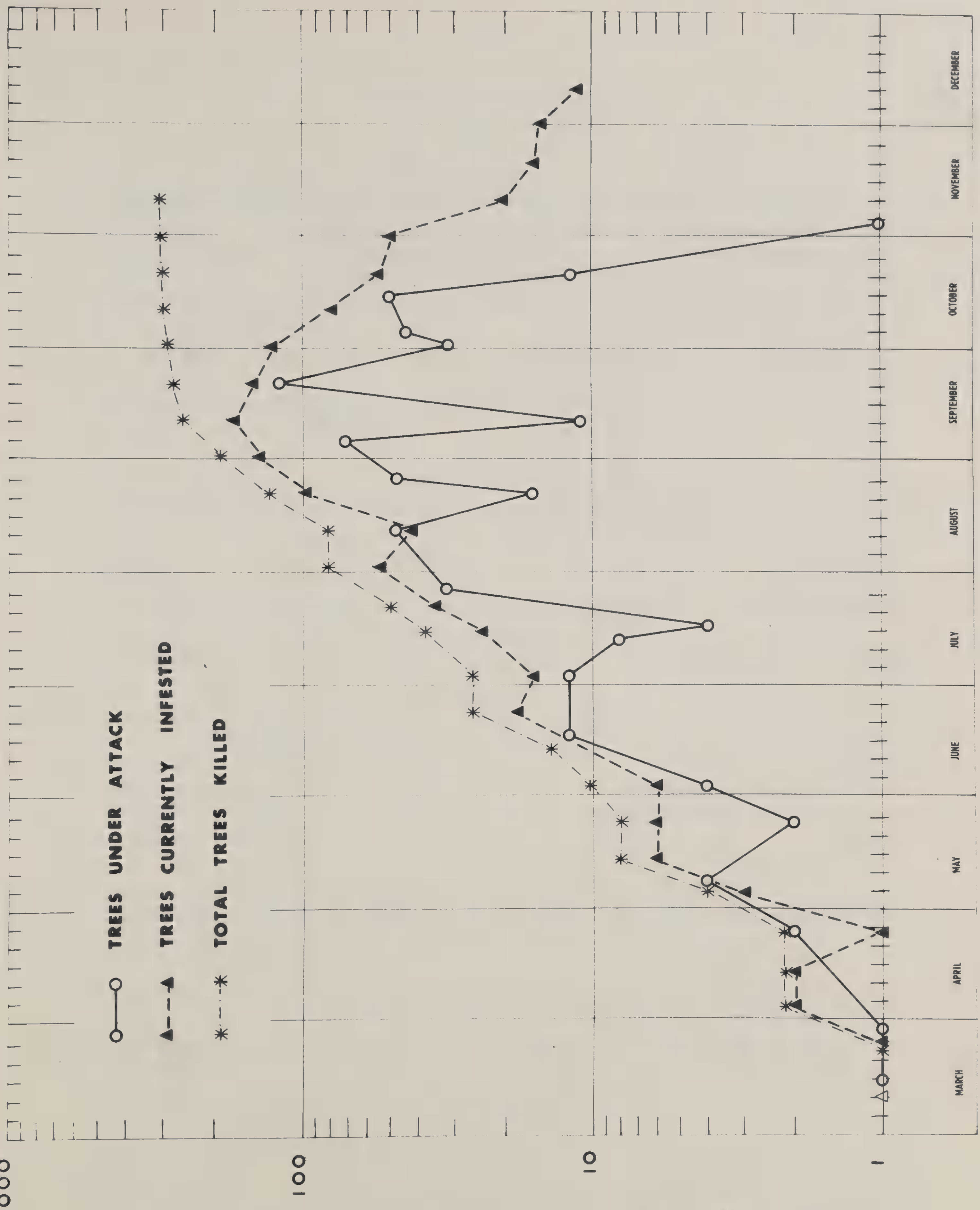


Figure 4. Projected hypothetical development of a southern pine beetle infestation assuming reemergence of parent beetles in 14 days and emergence of brood beetles in 40 days. One overwintering infested tree on March 10.

# PROCESSING SURVEY DATA

W. H. Clerke [1/]

Our speakers on Tuesday provided us with challenging information requirements for the seventies. Bob MacDonald emphasized the role of the computer in the massive task of analyzing data, a problem not limited to remote sensing. Both Dave Ketcham and Tom McLintock emphasized the need for impact surveys and up to date information. These speakers stressed the application of data collected in surveys to informing the public and in setting research priorities. Norm Johnson stressed realistic analysis of pest management problems consistent with the changing forest structure, and setting priorities. He also added a parting remark on the application of time-sharing computers in cooperative studies.

There is no doubt that computers will play an important part in the 1970's. The number of computers in use will double in the next decade (Larcher, 1970). The most important improvements will be in access to the computer. Remote computer access is in its infancy. It is estimated that there will be over two million remote computer terminals in use by 1975 (Larcher, 1970). At the same time the cost of storing information will drop drastically. It will be as cheap to store information in a computer as to print it on paper (Marill, 1970). Computer microfilm combinations will provide information storage at even lower cost.

Computers will play an integral role in two of the major phenomena of the decade, the "Information Revolution" and "Systems Analysis". Accurate information is the basis for rational decision. Decision making in the past has been based primarily on the manager's experience and memory. Current methods of assembling data are crude and inadequate. Part of the problem in the present pesticides crises is the result of our inability to provide available information to the specialists and managers. Other aspects of the pesticides problem result from a failure to ask the proper questions.

There is no doubt that systems analysis will play a major role in future decision making. A system is "an organized or complex whole; an assemblage or combination of things or parts forming a complex unitary whole". Obviously a spectrum of concepts could be covered by such a broad definition. The term may be used in reference to the analysis of complex biological phenomena or the design of a system to achieve a management goal. There are principles that are common to all systems studies. It is recognized that the whole is greater than the sum of its parts, stressing

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the relationship between the parts of the system. The analysis is of a dynamic structure rather than a static structure at a single point in time. Managers are involved in building a system to accomplish specific goals. Biologists are involved in trying to understand complex natural systems. The systems approach to problem solving and environmental management is dependent upon modern information and computer systems for input and analysis.

The modern information system has four basic components; computers, terminal devices, communications links and people. Until recently users in remote locations communicate with computers only indirectly. Time-sharing and remote batch computing permit direct connection of the computer and user at remote locations via normal telephone lines. The ease of access and rapid turn around time of these systems greatly expands the number of people and useful application of computers. This is especially true of survey problems which require immediate answers, and information systems. Acoustic couplers permit remote computer terminals to be connected to any telephone (Fig. 1). Presently teletype terminals are the least expensive general purpose terminals (Fig. 2a). These units provide a full alpha numeric keyboard plus special functions. With a paper tape punch (Fig. 2b) data may be prepared for transmissions prior to calling the computer; programs and data can be stored on paper tape for later use. Magnetic tape cartridge units have been developed to replace paper tape units on teletype time-sharing terminals. The cartridge, holding 150 feet of magnetic tape, can store 150,000 characters. One thousand feet of paper tape would be required to store the same data. Magnetic tape units can transmit at speeds up to 1,200 words a minute.

The increasing volume of remote computer processing is creating a demand for more advanced remote terminals. Modifications of the magnetic tape typewriter will permit its use as both an automatic typing unit and a remote computer terminal. Touch tone telephones are the least expensive unit for inputting data to the computer. Similar units that can be attached to any telephone are available at low cost. These units are suitable for inputting small amounts of data from field locations. Portable teletype units only slightly larger than portable typewriters will soon be available to provide computer service to personnel in the field. Terminals displaying input and output on a cathode ray tube are small and quite ideal for management information systems.

Analysis and data collection systems must function together. The time when the analysis was an isolated step -- often an afterthought -- is past. Survey data serves two basic groups of people. It provides the

basic information to aid the entomologist in understanding the causal factors in pest population fluctuations and in predicting population trends. It provides information to resource managers allowing them to make informed judgements of resource allocation. Data from a single survey can serve both users; the analysis, however, must be tailored to the needs of the user. Survey data collection systems should be thought of in relation to two time basis; immediate and long term. Surveys are usually designed to answer immediate questions and predictions. When survey data is available in a computer compatible form it can also be used to analyze trends over a period of years. There has been little sharing of data with related forestry disciplines. Time-sharing computer systems provide an opportunity for building common interdisciplinary data banks. Weather data, for example, collected for fire hazard prediction may be useful to entomologists in predicting conditions that lead to a buildup in insect populations.

It is imperative that we think of "Systems Analysis" and the "Information Explosion" not as a threat but as an opportunity. The challenges we face place responsibilities on both the specialist and the manager. For the specialist it will mean continuous education. The manager must strive to make full use of computers without abdicating his responsibilities in control and decision making. Both groups must strive to communicate to others in the resource field and the general public.

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Figure 1 - Acoustic Coupler - This unit permits the connection of remote computer terminals to standard telephones.

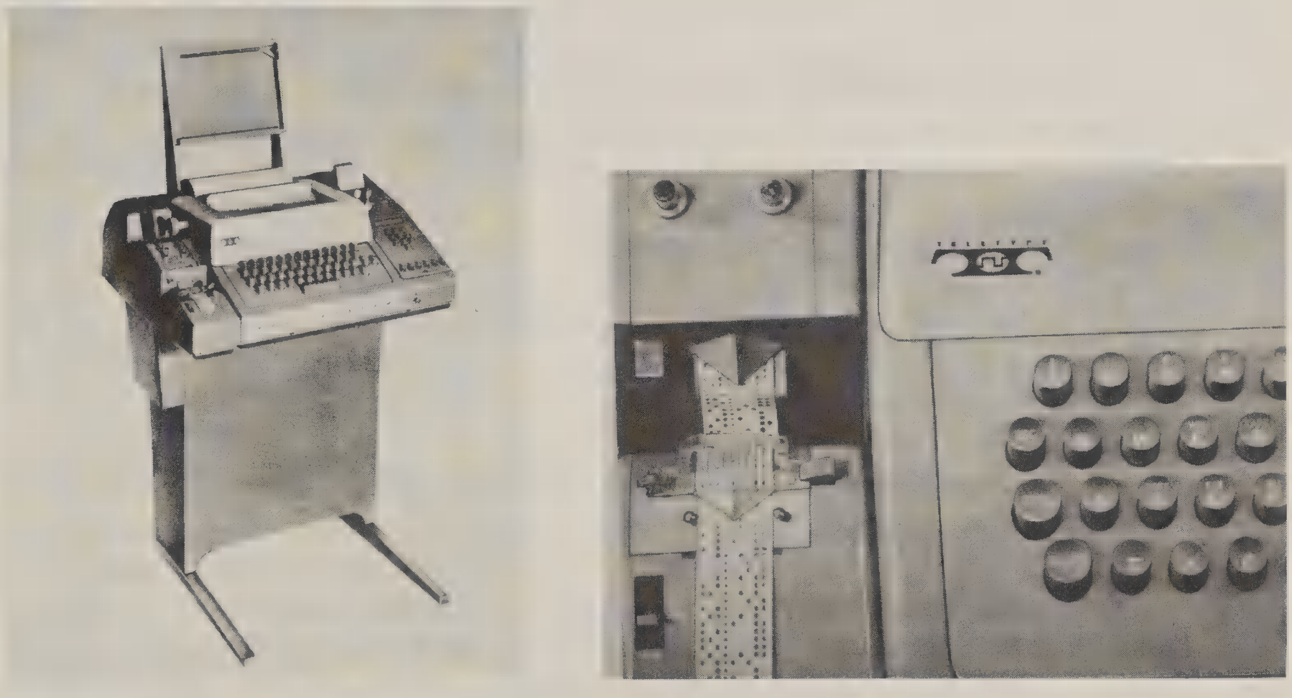

Figure 2 - A Model 33 Teletype Unit -

(a) Complete Unit (b) Closeup of paper-tape reader and punch.

PANEL ON AIR POLLUTION


Panel on Air Pollution - L to R, F.A. Wood, Associate Professor, Pennsylvania State University, University Park, Pa.; C.R. Berry, Pathologist, Southeastern Forest Experiment Station, Asheville, N.C.; D.D. Davis (Moderator), Pathologist, Zone 2, Alexandria, Louisiana.

# DIAGNOSIS OF AIR POLLUTION DAMAGE TO FORESTS

Francis A. Wood [1]

## INTRODUCTION

The principle objectives of this presentation are to outline the most important plant pathogenic air pollutants, to discuss the major sources of these pollutants, to discuss their specific effects on various types of plants, to review several case histories which illustrate the impact of various types of air pollution on forest communities, and to discuss some of the more subtle aspects of the field diagnosis of air pollution damage to forests. Before proceeding, I think it is important to ask the question, what is an air pollutant? As you might expect there are numerous definitions or concepts about what an air pollutant is. One of the simplest and most easily understood definitions is that an air pollutant is any ingredient of the atmosphere that causes an unwanted effect. Obviously,

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it is the unwanted effects caused by various air pollutants that have triggered the current interest in this problem. Most of us readily accept the fact that particulate matter and various gaseous substances are air pollutants. However, odors and noises which are also mediated by the atmosphere and often result in unwanted effects also constitute air pollution and are air pollutants. With these general comments in mind let us now consider what the most important plant pathogenic air pollutants are and where they originate.

## SOURCES OF PLANT-PATHOGENIC AIR POLLUTANTS

Sulfur dioxide, a pollutant known to be pathogenic to plants for well over 100 years, is emitted principally from the combustion of coal; the production, refining, and utilization of petroleum and natural gas; manufacturing and industrial utilization of sulfur acid and sulfur; and the smelting and refining of ores, especially copper, lead, zinc, and nickel.

The combustion of coal represents the major source of $SO_2$. The amount of $SO_2$ emitted depends upon, among other things, the sulfur content of the coal. The sulfur content of coal in the United States ranges from less than 1% to as much as 6% with 2% as an average. Coal-burning power plants are the most important single source of $SO_2$, and numerous instances of vegetation damage have been associated with this source.

Flourine-containing compounds, such as HF and silicon tetrafluoride ($SiF_4$), have been recognized as pathogenic to plants for over half a century. They originate principally from aluminum reduction processes, manufacture of phosphate fertilizer, steel manufacturing plants, brick plants, pottery and ferroenamel works, and refineries.

In general, the fluorides originate from the molten cryolite bath in the manufacture of aluminum and from impurities in the raw materials used in the other industries. Fluorides are toxic at much lower concentrations than most other plant-pathogenic air pollutants. Therefore, while the annual tonnages produced do not compare with those of pollutants such as $SO_2$, the fluorides still represent a major problem as phytotoxicants.

Ozone, usually a secondary-type pollutant, has been recognized as a phytotoxicant for at least 100 years. However, its role in the current air pollution problem and its origin in the smog over cities has been unraveled only during the past 10 to 15 years. Sources of $0_3$ can be classed as the upper atmosphere, electrical storms, and photochemical reactions.

Some meterorologists and pathologists believe that tropospheric $0_3$ may be brought to the earth's surface during atmospheric disturbances such as violent storms. It has also been established that $0_3$ may form during thunderstorms, as a result of the splitting of molecular oxygen by electrical discharge with the formation of atomic oxygen which subsequently reacts with molecular oxygen to form $0_3$. The ground level concentration of ozone increases during many of these thunderstorms, enough to cause injury to vegetation. Weather fleck of tobacco, a disease which has been associated with atmospheric disturbances for many years, is now known to be caused by $0_3$.

Probably the most important source of ozone today is photochemical reactions in polluted atmospheres. Oxides of nitrogen, which are emitted into the atmosphere by the automobile and a variety of industries and utilities, may react in the presence of light (sunlight) with oxygen to form $0_3$ as indicated in reaction 1.

Reaction 1

$$NO_2 + hv = NO + 0$$

$$0 + 0_2 = 0_3$$

$$N0 + 0_2 = N0_3$$

$$N0_3 + 0_2 = N0_2 + 0_3$$

Likewise, the irradiation of mixtures of oxides of nitrogen and various hydrocarbons often results in $0_3$ formation. Hydrocarbons emitted by motor vehicles; and oxides of nitrogen emitted by motor vehicles, industrial processes, and the generation of electrical power can react to form the secondary pollutant $0_3$, which is a major phytotoxic ingredient of "urban smog".

Peroxyacetyl nitrate has been recognized as a common phytotoxic constituent of the smog over cities for the past 10 to 15 years. Peroxyacetyl nitrate is one member of an homologous series of compounds which originate principally from the reaction of olefin-type hydrocarbons and oxides of nitrogen in the presence of light (reaction 2).

Reaction 2

$$\text{Olefin} + N0_x \text{ light } CH_3\text{-}C00N0_2$$

Peroxyacetyl nitrate, its relatives, and a number of other compounds, such as aldehydes, can form. Their formation depends on the type of olefin involved, on whether $N0$ or $N0_2$ is present, and on the duration of the time of irradiation. A few of these inter-relationships are shown in Table 2. Again, the automobile and other forms of transportation represent the major sources of hydrocarbons and oxides of nitrogen that function as reactants to form PAN.

Terpenes that evolve from coniferous vegetation can react photochemically with oxides of nitrogen to form ozone and PAN. Consequently, natural sources of hydrocarbons in the vicinity of man-related sources of oxides of nitrogen, such as power plants, could result in the formation of photochemical air pollutants.

Recently, oxides of nitrogen have been cited as a potential problem as phytotoxic primary pollutants, especially in view of the amounts of these compounds emitted annually. Oxides of nitrogen originate from a variety of sources which include gasoline combustion in motor vehicles, refining petroleum, combustion of natural gas, fuel oil and coal, and incineration of organic wastes.

Hydrogen chloride (HCl) was an important plant pathogenic air pollutant in Europe approximately 100 years ago. However, technological changes replacing the Le Blac soda process resulted in the disappearance of the HCl problem. In recent years there has been a reappearance of injury and damage attributed to HCl. Chlorine ($Cl_2$), which is also highly toxic to plants, has been implicated as the cause of damage to vegetation in several instances. These two chemicals are increasing in importance as phytotoxicants. Current major sources of HCl and $Cl_2$ include refineries, glass making, incineration and scrap burning, and accidental spillage. Polyvinyl chloride is used in large quantities in manufacturing packaging materials and wire insulation. Combustion of polyvinyl chloride results in the emission of HCl and a myriad of other compounds. The increased use of this material is one of the main reasons why it is thought that HCl will become more important as an air pollutant. Hydrogen chloride is soluble in water and techniques are available for efficiently scrubbing it from flue gases.

Particulates have been recognized as plant-pathogenic air pollutants for many years, however, there has been relatively little research on the problem. The major sources of atmospheric particulates include combustion of coal, gasoline, and fuel oil, cement production, lime kiln operation, incineration, and agricultural burning and agricultural-related activities.

## EFFECTS OF AIR POLLUTION ON PLANTS

In general, the symptoms of air pollution injury to plants can be classified as either necrotic, chlorotic or atrophic. Specific effects include changes in cell wall permeability, plasmolysis, changes in tissue pH, interference with cell wall synthesis, acceleration of respiration, inhibition of enzymes, and a reduction in the rate of photosynthesis. Effects are often classified as either acute or chronic, with acute implying some degree of necrosis of tissue. In contrast, chronic refers to all non-necrotic, usually more subtle effects. From a diagnostic viewpoint, the effects that specific pollutants have on a given plant can often be unraveled in the field. However, with two or more pollutants acting in consort, the differences are often masked and the resultant symptom picture is confused. Consequently, in many instances it is impossible on the basis of field observations alone to make a positive identification and implicate a specific pollutant.

Sulfur dioxide causes an interveinal chlorosis and necrosis of the leaves of broadleafed plants and usually a tip necrosis of the leaves of evergreens. There is often a reddish banding on the leaves of some evergreens, such as larch. On broadleaf plants such as pinto bean and alfalfa the interveinal necrosis is usually ivory colored; on broadleaf plants such as red maple the interveinal necrosis is often reddish brown. The tip necrosis of evergreens is usually characterized by a dead needle tip with a chlorotic "band" between the necrotic area and the healthy tissue. On many evergreens there is often a premature defoliation of older needles which ultimately results in a reduction in growth rate.

The reduction in growth rate of conifers may be quite dramatic and may occur with little apparent injury to the foliage. An opportunity to examine the effects of effluents from coal-burning power plants on the growth rate of white pine was presented by a peculiar sequence of events which I shall outline.

In 1952, a coal-burning power plant was constructed with four 200-foot high stacks. It was situated in a valley and the height of the smoke stacks essentially coincided with the height of the surrounding ridges. Shortly after the plant began operation, vegetation was damaged and the damage was attributed to the power plant. Finally, in an effort to alleviate the situation, a 600-foot high stack was constructed and put into operation in 1962. The increase in stack height of 400 feet would provide for better dispersion of the plume and theoretically reduce ground level concentrations of $S0_2$. In the summer of 1966, we examined vegetation to the northeast of the plant. At several locations, the annual height and diameter growth of eastern white pine was measured for a period of five years prior to the construction of the tall stack in 1962 and the years following the construction of the tall stack.

The increase in stack height resulted in a reduction in ground level concentrations which is reflected in the growth pattern of the trees. Relatively speaking, the reduction was greater near the stack than it was at distances farther away. An examination of the growth data showed that eastern white pines were growing at a faster rate since the construction of the tall stack than they were before. The data also show that there was an inverse relationship between the amount of increase in growth rate and distance from the source. The increase in growth rate of the trees since the construction of the tall stack clearly shows that there has been a reduction in the ground level concentration as was anticipated.

Hydrogen fluoride, in contrast to $SO_2$, causes a marginal chlorosis and necrosis of the leaves of broadleafed plants and tip chlorosis and necrosis of evergreens. Fluorides in general are highly mobile within the plant. Instead of causing injury at the point of entry, for example in the interveinal areas, they often move to the margin of the leaf where they accumulate and eventually cause damage to sensitive plants. Because of their mobility and ability to accumulate in certain plant tissue, and because of their extreme toxicity (atmospheric concentrations of one part per billion (ppb) may result in injury to some plants), fluorides represent a special type of problem.

The ability of fluorides to accumulate in vegetation and their toxicity to animals have resulted in an additional problem. Cattle grazing on vegetation in the vicinity of fluoride sources often develop the disease known as fluorosis. This is caused by the fluoride taken in during foraging. The fluorides interfere with blood and bone metabolism which results in a blackening of the teeth and an overall debilitation of the animal. There have been some serious outbreaks of fluorosis in cattle herds in the western United States.

Ozone damage to plants is often characterized by a metallic flecking or necrotic stippling of the upper leaf surface of broadleaf plants. The upper leaf surface effect is due primarily to the fact that the palisade cells are much more sensitive to $0_3$ than are the spongy mesophyll cells. Our knowledge of the effects of ozone on forest trees has increased markedly in recent years. On broadleafed plants such as the ashes, oaks, tulip poplar and others the most common symptoms are either a chlorotic or necrotic stippling of the upper leaf surface. With conifer species such as many of the pines, larches, and hemlock the most common symptoms are chlorotic mottling, chlorotic banding, and tip necrosis of the needles.

As was mentioned earlier, $0_3$ may originate during certain storms and, as a consequence, relatively high concentrations of $0_3$ may develop in rather remote areas. This "natural" occurring $0_3$ has been implicated as at least a part of the causal complex of the needle blight syndrome of eastern white pine and of weather fleck of tobacco.

Ozone that develops photochemically in the atmosphere over cities is not necessarily confined to the city. In recent years, the chlorotic decline of ponderosa pine in the San Bernadino Mountains east of Los Angeles has been attributed to $0_3$ that originates in the smog cloud over Los Angeles. The chlorotic mottle observed on the older needles in the field has also been duplicated in fumigation chambers with $0_3$. Hence, photochemical air pollutants, such as $0_3$, that develop in the atmosphere over urban centers may be carried to adjacent forest areas and cause damage as far as 50, 60 and 70 miles away. This prospect can be quite alarming when one considers the megalopolis that extends from Boston, Massachusetts to Richmond, Virginia, and the millions of acres of forest land within a radius of 60 to 70 miles of this megalopolis.

Peroxyacetyl nitrate, in contrast, to $0_3$, causes symptoms to develop for the most part on the lower surface of the leaf. The symptom that develops most often is a glazing or silvering of the underleaf surface which may develop into a necrotic-type symptom. This glazing or silvering is due primarily to a destruction of spongy mesophyll cells and the subsequent movement of air into the area of the leaf between the lower epidermis and the palisade cells. At the present time we know essentially nothing of the effects of PAN on forest tree species. Preliminary fumigations in our laboratory indicate that the 34 species tested are in general more resistant than vegetable crops and other herbaceous plants that have been studied with respect to sensitivity to PAN. However, it is important to realize that these statements are based on preliminary studies and that it will be several years before such a generalization can be stated unequivocally.

As far as relative toxicity is concerned, $S0_2$ is the least toxic and HF the most toxic of the above four compounds. Ozone and PAN are intermediate in toxicity, with PAN slightly more toxic than $0_3$. Of course, many factors are important in determining the severity of plant response, including degree of susceptibility of a given plant, the nature of environmental conditions during fumigation, the concentration of the pollutant during fumigation, and the length of the fumigation.

In addition to the above effects, air pollutants may also cause synergistic effects, potentiative effects, and predisposing effects. For example, a true synergistic effect has been shown with $S0_2$, $0_3$, and tobacco plants.

Tobacco plants exposed to very low concentrations of $SO_2$ and $O_3$ simultaneously were more severely damaged and the effect was greater than the additive effects on plants exposed to the pollutants individually. Similar synergistic effects have been obtained more recently with other species of plants and other combinations of pollutants. The exposure of long-lived plants, such as trees, to low, continuous or intermittent, concentrations of various air pollutants may result in a gradual weakening and predisposition of such plants to attack by relatively innocuous pathogens.

## ADDITIONAL CONSIDERATIONS

In the field diagnosis of air pollution damage to forests, there are several basic factors to be considered. Among these are: nature of the source, i.e., single, multiple, or area, topography or pertinent terrain features, meteorology, the interaction of terrain and meteorological features, biological factors such as uniformity of symptoms on a given plant, variety of species affected and pattern of distribution of symptoms with respect to the source. In addition, with pollutants such as $SO_2$ and HF residues accumulate in the foliage and can be used as an indication of the existence of a problem. These facts are relatively easy to integrate in the solution of problems where there has been a sudden gross insult on the ecosystem. In contrast, an examination of vegetation around long standing sources may reveal a relatively low incidence of occurrence of damaged individuals. In my opinion, in these situations the apparent low incidence of damage is due to the fact that susceptible members of the populations have been gradually eliminated as a result of exposure over a long period of time. This kind of thinking can be applied to cities that have developed around a heavy industry or where there has been a gradual increase in vehicle traffic with time. It may also apply to areas in the vicinity of smelters or power stations where these units have been in operation for many years. In situations like these, it is often desirable to examine recently established plantations and other types of plantings.

In summary, there are a variety of factors that one must keep in mind as he attempts to evaluate and diagnose alledged air pollution damage to forest communities. Just as in the case of other forest tree diseases, accurate diagnosis is indeed dependent upon knowledge of these factors and the subsequent integration of this information.

# AIR POLLUTION INDICATORS IN FOREST STANDS

Charles R. Berry [1/]

All air pollutants are classified either as aerosols or gases, and as an opener I think it might be well to spend a few minutes on definitions. An aerosol is a minute particle, either solid or liquid, so small it can remain suspended in the atmosphere for a long period of time. There are four kinds of aerosols, as follows:

1. Smoke contains solids and liquids and is the product of incomplete combustion.

2. Fumes are solid particles generated by the condensation of vapors, usually volatilized from the molten state of solids.

3. Dusts are solid particles released chiefly from grinding, drying, sawing, or dusting processes.

4. Mists are liquid particles, such as fog and steam.

In forests we are mainly concerned with gaseous phytotoxicants. There may be hundreds of different gases in a given atmospheric regime. The gases with which we are mainly concerned are relatively few in number. These include sulfur dioxide, ozone, fluorides, oxides of nitrogen, ethylene, and PAN (peroxyacetal nitrate and related compounds).

Air pollution injury to plants generally becomes evident before visible effects can be noted on either animals or materials. This high sensitivity, coupled with their low cost, makes plants valuable as bioindicators.

Plants can be valuable as air pollution bioindicators in at least five ways:

1. Recognizing the presence of airborne contaminants.
2. Determining distribution of the pollutants.
3. Estimating the level of pollution.
4. Providing a passive system for collecting pollutants for later chemical analyses.
5. Identifying directly the different air pollutants on the basis of plant species injured or symptoms produced.

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1/ Principal Plant Pathologist, USDA, Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.

This is not to say that green plants will soon eliminate the need for sophisticated instrumentation in combating foul air. There are limitations, of course, particularly those brought about by the environment. If quantitative measurements of specific fumigations are needed, then instrumentation is a must. If, however, one needs only to estimate levels, or show the presence, absence, or distribution of pollution, then plants may work as well as, and at lower cost than, instruments.

Annuals have been used extensively as bioindicators and are still of tremendous value because they are often cultivated as ornamentals or field crops in problem areas. An evergreen perennial, such as a pine tree, however, can have several advantages over annuals:

1. Evergreens are sensitive for longer periods of time, throughout the year if selected clones are used, whereas herbaceous plants are sensitive only for short periods and then must be replaced by younger plants.

2. Evergreens of known sensitivity can be planted and grown as permanent monitoring devices in areas where air pollution problems are expected to arise or increase.

3. With potted evergreens the same plant can be repeatedly exposed and reactions compared in different locations.

4. Certain evergreens can be grown under wide temperature and humidity ranges. It is not yet completely understood, however, how changes in temperature and humidity will affect the sensitivity of plants.

It is possible to identify five phytotoxicants by the symptoms produced on broadleaf plants, as follows:

| Phytotoxicant | Tissue most affected | Symptom |
|---|---|---|
| $SO_2$ | all mesophyll | Interveinal blotching |
| $O_3$ | palisade cells | upper surface fleck |
| PAN | spongy mesophyll | lower surface glaze |
| F | all mesophyll | death of tips and margins |
| ethylene | entire plant | drooping of foliage resembling wilting |

Although at this time symptoms produced on conifers are not as well defined as on broadleaf plants, we are confident that research will provide a great deal more information in this area.

A word of caution is needed for those who evaluate air pollution injury; however, because symptoms produced by pathogenic organisms are often similar to symptoms produced by air pollutants.

The influence of environmental factors on the degree of injury caused is one of the most important yet poorly understood areas of air pollution research. Research on environmental factors requires sophisticated equipment to reproduce nature under closely controlled conditions. Yet growth chambers with light intensity equal to a normal summer day, 10,000- to 12,000-ft. candles, cannot maintain this intensity for more than a few hours. We know, however, that sunlight predisposes many plants to injury and is a very important consideration. Thus, open-grown trees are often injured more than shaded trees.

Soil moisture and humidity are known to be of utmost importance. When either is high, plants tend to be more susceptible. Soil fertility also seems to be important, with high nutrient levels apparently offering some degree of tolerance.

In conclusion, I would like to emphasize that green plants, either planted or growing wild, can be useful in carrying out bioassays of air pollutants. Certain tasks, particularly those of a survey nature, can be performed as well or better with plants as with instrumentation. Trees, particularly evergreens, promise to be more useful than herbaceous plants, so widely used in the past. A word of caution; however, is needed for those who may need to evaluate air pollution injury because the influences of environmental factors can complicate a bioassay and the possibility of similar symptoms being produced by pathogenic organisms must be considered.

## PANEL ON PREVENTION AND CONTROL


Panel on Prevention and Control, L to R - L. E. Drake, Entomologist, Zone 2, Alexandria, Louisiana; J. L. Rauschenberger, Zone Supervisor, Asheville, North Carolina; G. L. Downing (Moderator), Entomologist, Area Office, Atlanta, Georgia. Several members of this panel were absent when photograph was taken.

## PILOT PROJECTS

John L. Rauschenberger [1/]

We are today at what I consider a critical point in our overall pest management programs. Never have the projected figures on future needs for raw wood products from the southeast been so high. I don't think it necessary to state specific figures on what our southern woodlands are going to be required to produce by 2000 - Sufficient to say that production per acre must go up. One of the primary prerequisites to increasing production is decreasing the losses caused by forest insects and diseases.

The responsibility is all of ours for using the most current and improved methods in prevention, detection, evaluation and suppression to reduce these losses. We must therefore, at every opportunity, gather and evaluate new research results in these endeavors. Based upon this research, we

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1/ Field Supervisor, Division of Forest Pest Control, State and Private Forestry, Southeastern Area, Forest Service, Asheville, North Carolina

must decide if that particular method, piece of equipment or agent could be used in a practical manner by the land manager to reduce his losses. If it is decided that the method or agent does look promising, it is evaluated and tested in what is termed a Pilot Project. It is the explicit purpose of a pilot project to bridge the gap between promising research and the possible adoption of the system for use in action programs in the field.

Stating it another way, it is simply the carrying of a promising system into the field for a practical trial to test it in action under actual field conditions.

Very briefly, I'd like to relate what a typical pilot project by the Division might consist of:

First, it would include a detailed work plan subject to approval at the Regional as well as Washington Office level. Pilot projects are usually very expensive; therefore, financing and manpower must be arranged. Also, in this work plan, the objectives, methods, procedures, etc. would be spelled out in detail.

Secondly, the statistical design of the test would be carefully planned and closely examined by a biometrician to insure high levels of confidence in the resultant data.

Test sites and conditions would be carefully selected so as to represent the widest possible range of future proposed usage.

In the case of a chemical control pilot test, safety to personnel involved in the test, especially in the use of a toxic chemical, would be carefully planned. Also, arrangements for any biological monitoring of the test would be made with appropriate agencies.

Reporting of the results of a pilot project, one of the final phases, is also one of the most important. The best data, if not presented in a clear and concise form suitable for the land manager's use, is worthless.

Although there are many other considerations in a typical pilot project which would vary with the test, the ones just mentioned are the primary ones and I hope by relating them, I have conveyed the essence of what a pilot project entails. I'd now like to single out several areas where we believe pilot projects of the future will play a dominant role.

First, in the areas of evaluation and detection of forest insects and diseases:

Joe Bell yesterday gave you a good rundown on the promising future applications of remote sensing. You may consider his work in this area as a pilot project. He is taking the results of research from many quarters and from it is developing procedures, methods, and techniques which will be applicable to our needs in pest management.

You also heard this morning from Bill Clerke concerning the future applications of the computer for analyzing survey data. This, once again, is an example of taking basic research information from many sources and developing and testing it for our needs in evaluation.

Additional pilot projects are contemplated in other areas of detection and evaluation. New methods of sampling specific insects and diseases in order to predict future losses is sorely needed. As research information continues to become available on life tables, biology and growth impact of the various agents, projects will be initiated to carry this information into the field in the form of practical sampling plans for testing and hopefully, ultimate use by the land manager.

Evaluation and control of insect and disease agents in seed orchards, nurseries and seed production areas is another area that will demand ever increasing attention in the future. There are some very unique problems in these areas that will demand some very unique answers. Pests that we consider of little economic importance on the forest take on a very significant role in these areas. It will be imperative that evaluation and control methods based on current research be developed for these high value areas.

Air pollution evaluation is another area that will demand a great deal of our attention in the future. As you have already heard from the preceding panel, methods are being developed for its appraisal.

I believe it is fairly obvious but possibly should be pointed out that the research upon which a pilot project in detection or evaluation is based need not necessarily come from forestry oriented research. It can and has often come from such widely diversified sciences as agriculture, mechanical and photographic engineering and even NASA. In the choice of photographic films, for instance, one could even cite the Department of Defense as a source of our research information.

Our objective is to bring these sciences together, focus them on our problems, evaluate them and ultimately pilot test them as to effectiveness in our program.

I would now like to turn your attention to another area of pilot projects -- that being the area of suppression or control.

There are several different types of control -- chemical, biological, integrated and silvicultural. Let's first consider the pilot projects or tests involving direct chemical control.

When one thinks of a suppression project against an insect or disease, he automatically thinks about how well the spray or dust or predator controlled the insect or disease and this is fine. This, however, is not and can not be our only concern - not only must we find and utilize more effective control measures based upon the most current research, but these measures will need to meet future standards of safety and be within tolerable environmental pollution limits. Such things as hazard to human health, movement in the natural environment, concentration in food chains and all other unintentional effects will in the future, even more so than now, need to be considered in all of our control efforts right along with the effectiveness against a target insect or disease.

In light of the aforementioned facts, our overall goal in direct control is relatively clear -- reduce pest losses so future wood demands can be met and do it in such a way that potential risk of unintentional effects are minimized.

Why and in what situation will future pilot tests of control methods be conducted? Obviously, the first consideration will be determination of the need. How effective and safe is the present recommended control if there is any; and is there a need for improvement based on the losses occurring? Also it must be determined whether any alternative indirect preventative type action might be taken in lieu of direct control measures. Unfortunately, many of today's chemical control measures can be considered as last-ditch, stop-gap, or last recourse types of action. To illustrate this point, consider for a moment an insect outbreak in a forest stand and suppose it's slated for chemical control. One big fact emerges from this supposition -- it's now too late to think about such things as -- are the trees off-site, is stocking optimum, are the trees overmature and stagnating? The time is long past when any indirect action might have been taken to have staved off or lessened the intensity of this insect attack. All that is known is that losses are occurring and that chemical control is now our last recourse to saving the resource.

This situation of needing adequate chemical control measures at our immediate disposal is not going to change anytime in the near future. Protective, indirect non-chemical control measures are something which must be built in -- not added on after a forest stand is established. Until

we more fully understand the complexities of such things as host resistance, site-host compatability, and biologies of both the host and the insect or disease agent, we must continue to live with the chemicals and do everything possible to insure that we're using them in the best way possible. The determination of this is one of the primary functions of pilot testing.

The need for future pilot testing of chemicals can be further illustrated by citing an example and asking this question: How would you generally compare the advancements of our present day S.P.B. control program against the advancements that have been made in detection and evaluation of this same insect? Keep in mind that this insect constitutes one of the worst insect threats to our pine in the South.

Let's look at it. We have and are now using on an operational basis aerial photographic techniques of detection and evaluation. Other remote sensing methods such as discussed yesterday promise even more efficiency in the future. Radiography to determine beetle brood density is likewise presently used on an operational basis. Processing of survey data with the aid of computers as discussed here is right around the corner. Yet, with these advancements in evaluation, our chemical control measure for the southern pine beetle has not really changed in 10 years.

I do not mean to imply from this example of the southern pine beetle that our present control methods are the weak link in all cases. There have been some great strides made in the control field. (1) L. V. malathion, (2) irradiation of male screwworms, (3) mirex for ants, are prominent examples. These are cases where control techniques have indeed kept up with the other aspects of the program but, in the cases where control has not kept up for reasons of effectiveness, safety, contamination and economy, future pilot testing of promising research results will be essential.

The most basic decision to be made in pilot testing, now as well as in the future, is what constitutes a promising control agent and why it is chosen for testing. This choice of chemical, like that of a detection or evaluation system, is based almost exclusively upon current research results. One of the chief sources of such information regarding chemicals is the U.S. Forest Service Forest Experiment Stations. Upon them fall the responsibility of laboratory testing of a chemical. Upon success of a given agent in the lab and possibly even in a limited field trial, a control agent would become a candidate for pilot testing.

Research from other sources is also utilized when considering an agent for pilot testing. Universities, private wood industry labs and chemical manufacturers have and will probably continue to provide valuable information. Research laboratories of foreign countries can also be a good source of information.

Irregardless of the source or sources from which promising chemicals emerge, the speed with which they are carried into the field for pilot testing is and will in the future, be of primary importance. Lags in time between promising research results and ultimate recommendation for use to land managers must be cut down. We must constantly strive to recommend the most current and effective control available. While this need for fast development and testing of promising control methods is ever with us, likewise is the need for caution. It would be very convenient and would not cost much to test agents on a very hasty and limited scale. With such testing, we would be placing ourselves as well as the land manager in a very compromising position. Your imagination is the limit for things that could go wrong with an untested agent being used on a commercial field scale.

To insure the land manager against the unexpected, a pilot test must give as much attention to the side effects of an agent as it does to the effects on the target insect or disease. All tests involving the use of toxic chemicals must be biologically monitored to measure its effect on the environment and the ecological systems present. Biological monitoring in the future, as in the past, will cover a wide range of activities on the test site. Trapping of rodents and birds, collection of soil and water samples for residue analysis and plant tissue analysis are but three of the most common monitoring activities which might be initiated in a pilot test. This monitoring is usually carried out cooperatively by biologists of Federal, State or private agencies -- each a specialist in hiw own aspect of the environment. We have found the biologists from these agencies quite capable of and usually quite willing to cooperate in monitoring a pilot test of a toxic chemical.

This biological monitoring in the environment promises to be an even more important function of pilot testing in the future. This nation's growing concern over pollution will not decrease. As we all know, from watching the national picture, the opposite is true -- anything that contributes to soil, air or water pollution, irregardless to what degree, promises to receive close attention in the future and even regulation and restriction where deemed necessary. Chemical means of control fall into these categories.

As to the specific chemical control tests of the future, it is relatively hard to predict what they will be much beyond a year from now. With research working on such a wide diversity of problems, and with technological data progressing at the ever increasing rate, it is impossible to say what developments will make a particular control agent or measure look promising say, five years from now. For instance, in just the field of chemical control measures, there are presently over 8,000 manufacturing firms in the United States that combine about 500 chemical compounds into more than 60,000 formulations, the greatest percentage of them registered as insecticides. While this may or may not be in our favor, it is an indicator of the accelerated rate of technology and we are confident that promising new, improved means of chemical control will continue to evolve at the same increased rate.

Although I have, in this presentation, pointed up the need for future developments in chemical control, I also wish to emphasize the fact that chemical control measures alone will in all probability never solve all of our pest problems. As implied by DeBach in his book titled "Biological Control of Insect Pests and Weeds", our ultimate salvation does not lie at the end of a spray nozzle! He goes on to state that although his outlook is long term, he believes that only the biologist will ultimately find the answers to the basic problems in pest control.

Whether right or wrong, I think we all must agree that emphasis in biological control is like a ball rolling faster and faster. Promising research in this field is evolving at an ever increasing rate. Such things as pathogens, parasites and predators have been successfully utilized against a number of pests. The research outlook for the use of these biological control agents against some of our noxious forest pests is generally good. Some agents have failed outright, others show limited possibility and still others have shown a degree of promise. We are confident, from present research results, that the days are not far off when a number of these agents will be ready for mass rearing or culturing to pilot test on a field basis.

Another area of control showing high promise are the chemosterilants and sex attractants of insects. Great strides are being made in this field also. I personally feel that the sex attractants and chemosterilants used in combination with other chemical and biological control means is where our biggest breakthroughs are going to come in pest management. What I imply by this is the integrated control concept.

We must and will be conducting pilot projects on promising research to the extent manpower and finances allow to keep control methods as far advanced as possible. In supplementing our anticipated increase in pilot project activity, there is obviously the need for close cooperation and coordination with research. Toward this end, Division - Research Coordination Meetings have been held for the past several years with future ones scheduled.

One of the most fruitful things that has and will continue to come from such meetings is a transfer of thoughts and ideas -- we can relate what our problems are in the field, and research can in turn relate the most recent research findings. This we believe will cut down the costly lag between the release of information by research and its practical application in the field.

We are confident that the future holds the development of vastly improved methods of prevention, detection, evaluation and suppression. How far in the future they are, it is impossible to say. It is our purpose and goal, hand in glove with research, to put them to work in the field at the earliest possible time through pilot projects.

## REMOVAL OF INFESTED TIMBER BY COMMERCIAL SALES

L. E. Drake [1/]

The control of bark beetle infestations by timely removal and utilization of infested trees has been recognized as an effective approach to suppression for many years. This approach has been used to suppress, with varying degrees of success, certain bark beetle outbreaks in the United States as well as in other countries around the world. For many years, in the southeast, this approach to control has been a standard recommendation for the suppression of pine engraver beetle, *Ips* spp., outbreaks, especially in areas where natural disasters have occurred. However, when massive southern pine beetle, *Dendroctonus frontalis* Zimm., outbreaks occurred throughout the southeast area, from Virginia to Texas in the late 1950's and early 1960's, there were two basic reasons why, generally, it was thought that this approach to control would not be practical. First, there was only a very limited market for beetle infested, blue stained wood. Secondly, because we were dealing with a 6 or 7 generation a year insect with a tremendous biotic potential, it was generally

1/ Entomologist, Division of Forest Pest Control, State and Private Forestry, Southeastern Area, Forest Service, Alexandria, Louisiana

thought too much time would be required to go through the procedures necessary to remove and utilize the infested material; thus, the result would be to "spread the beetle population". For these reasons, chemical control was emphasized. The procedure involved cutting and spraying individual trees with a solution of benzene hexachloride (BHC) and diesel fuel. After trees were felled, they were limbed, topped, bucked into workable lengths and then sprayed. This was a very costly, time consuming procedure. Cost figures per tree treated varied considerably between projects, but generally ranged from \$1.00 to \$10.00 depending on accessibility, size of spot, and distance between spots. These extreme costs, coupled with the fact that epidemic beetle populations were continuing and areas of infestation were increasing in spite of intensive chemical control efforts, caused those involved to take a second look at the possibility of control by removal and utilization. In 1962, the state of North Carolina, confronted with a southern pine beetle epidemic in which more than 200,000 trees were infested, embarked on a large scale cooperative suppression project with emphasis shifted from chemical control to removal of infested trees by commercial sales. This project, involving the State, U.S. Forest Service, Forest Industry, and small landowners, was carefully planned and coordinated. After overcoming certain technical, legal, and administrative problems, the epidemic was brought under control and the project was considered successful. Cost of removal averaged approximately \$.25 per tree. The Division of Forest Pest Control, faced with increased costs of control projects, the questionable success of chemical control of southern pine beetle outbreaks, and increased public sentiment against the widespread use of pesticides, began to emphasize removal of infested timber by commercial sales to control southern pine beetle infestations. Currently, the Division of Forest Pest Control is recommending an integrated approach to control with emphasis on timely removal and utilization. Chemical control is used only as a last resort in situations where removal is not economically feasible due to inaccessibility of infested areas or poor local market conditions.

This approach to control is a relatively complex technique in which timing and coordination are very important and requires a conscientious effort on the part of the land manager, buyer, and processor if it is to be effective. Infested material must be detected, marked, sold, harvested, and utilized before the beetles emerge. When dealing with an insect that completes its life cycle in 30 days or less, the importance of timing and coordination can readily be seen. As was expected, some problems arose when this technique was implemented. In the southeast area, southern pine beetle problems exist in the mountains, Piedmont, and Coastal Plain's areas. Problems have been encountered in each of these areas that are unique to that particular area. However, in the

interest of time, I will briefly mention some problems that are generally common to all these areas. Perhaps the most serious problem has been the "poor market" for beetle killed timber; obviously, in order to have a salvage program, you must have a market. This problem has been greatly reduced by State and National forest people encouraging processors to procure and utilize infested material. The idea was stressed that, ultimately, it was their resource that was being threatened. One example of how some pulp mills that were procuring on a quota basis, cooperated in the southern pine beetle control effort, was their agreement to purchase and give priority to beetle infested wood in addition to the normal quotas. As a result, loggers became interested in "moving" beetle killed wood, especially after the quotas were filled. An important factor in developing a market for beetle killed-blue stained sawtimber was educating the public regarding the research work by Chapman et al. which showed that this timber was not structurally weakened. Some degrade loss is charged however. Dead sawtimber is selling for between $8-20/MBF and green infested sawtimber for $15-25/MBF. The stumpage value of this timber is influenced by accessibility, degree of deterioration, and size of spot.

Another serious problem is the land manager's inability to sell infested material in small and sometimes inaccessible spots. This problem has been minimized on National forest land by selling, in addition to the infested and dead material, a 40-70 foot buffer strip around the spot. This removes the "attractive head" of the beetle spot, thus minimizing the possibility of a "break out" and may provide an operable cut for the logger. As a last resort, spots that are inaccessible and cannot be sold are treated chemically.

During the winter months, the southern pine beetle tends to infest a greater portion of the tree including the tops and larger limbs. When infested trees are salvaged, large numbers of beetles are left in the woods. Recent preliminary research results indicate that by cutting a buffer strip around the spot, the insects remaining in the tops, upon emergence, find no attractive trees and, therefore, a high proportion perishes during dispersal. Also, indications are that predatory insects which are allowed to develop as a result of no chemical treatment, take their toll of the beetles remaining in the tops.

In 1966, the Division of Forest Pest Control, after consideration of these and other problems and consultation with research scientists, drew up a set of guidelines which suggested procedures to follow for southern pine beetle control. The portion of these guidelines that refer to beetle control by removal of infested material by commercial sales, reads as follows:

## SOUTHERN PINE BEETLE CONTROL METHODS

1. Removal of Infested Trees by Commercial Sales

a. When infestations occur in trees of merchantable size and are readily accessible, infested trees may be removed by commercial sales or administrative use procedures. Because time is of the essence, start logging of the infested material immediately and complete within the period of time stated in the permit or contract.

b. Lop and scatter tops to permit rapid drying which make them unfavorable for the development of Ips brood.

c. Where mills are situated on or near the area of infestation, process infested material promptly. Destroy slabs and infested bark by burning or chipping.

d. When only a small volume of infested material occurs in a spot and the infested trees are of merchantable size, it may be necessary to mark enough non-infested trees surrounding the infested spot to provide an operable cut. Experience shows that removal of a ring of non-infested green trees from around the edge of the infested spot effectively minimizes reinfestation. Remove infested trees first.

e. In order to minimize the possibility of spreading the beetle infestation, process beetle infested material at mills within or near the infested area whenever practicable.

Now what does all this mean? What have been the results of emphasizing southern pine beetle control by removal of infested trees by commercial sales? It is generally agreed that this approach has been effective. This is based on the fact that beetle population levels have declined and areas of infestation have not enlarged significantly. Suppression costs have been greatly reduced. Figures of one national forest show an 80 percent reduction in control costs per tree. Currently, timely removal and utilization is being emphasized on all Federal, and State and private lands in the southeast area where the southern pine beetle is a problem. I do not have figures for the entire area, but on the National Forests in Texas, approximately 70 percent of all spots detected last year were controlled by this technique.

In keeping with the theme "A Look Ahead" -- what does the future hold in bark beetle suppression? Hopefully, the day will come, when, through continued research, bark beetle outbreaks can be controlled either by biological agents, i.e., parasites, predators, or insect pathogens, or

preferably, through proper management practices that would render our forests less susceptible to bark beetle buildups, thus minimizing the need for control. Until these developments come to pass however, integrated control of certain bark beetle populations, with emphasis on removal of infested trees, will be continued in the Southeast Area.

In brief summary, the Division of Forest Pest Control is now recommending an integrated approach to southern pine beetle control with emphasis on timely removal and utilization. Removal has been effective and costs have been greatly reduced when compared to chemical control. Chemical control is used only when removal is not economically feasible.

## PLANNING SALVAGE OPERATIONS FOLLOWING HURRICANES

H. W. Echols [1/]

On August 17, 1969, at approximately 10:00 P.M. (CST), Hurricane Camille invaded Coastal Mississippi. Tides reached 26 feet above normal, flooding over 200,000 acres. Winds were reported to have been over 200 MPH. By 6:00 A.M. the next morning hurricane force winds of 100 MPH had traveled over 100 miles inland. Timber damage of various degrees extended over 15 counties. Approximately 1.2 billion board feet of timber and almost 1 million cords of pulpwood were damaged.

Within the theme of this Work Conference "A Look Ahead", I shall attempt to point out to you, from our experiences, plans for salvage operations following hurricanes which may occur in the future. My remarks will be directed primarily to organization and mobilization and some specific problems that may be encountered.

In planning to salvage timber under such circumstances, there are several factors which should be taken into consideration. They include:

1. Magnitude of damage in volume and acreage
2. Geographic location
3. Timber type
4. Degree and amount of damage to residual stands
5. Season of year
6. Potential danger of an insect epidemic before salvage can be completed.

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1/ Director, Department of Pest Control, Mississippi Forestry Commission, Jackson, Mississippi

These factors may influence the time in which to carry out a salvage operation.

## Organization

The first immediate concern following such a disaster is assistance to human needs. When cities, towns and communities are involved, every effort should be directed toward opening up streets and highways and clearing trees and debris from utility and power lines. As in our case, it was necessary to move men and equipment in from outside the storm area to assist in this need. Commission personnel who had been put on alert the day before, were engaged in this work within three hours following the hurricane. When additional assistance was available, work was then directed toward clearing county and woods roads to open ways for combating the dangerous fire situation. This effort can be coordinated through your Civil Defense Agency.

The burden of developing a coordinated salvage program falls on the State Forestry Agency. The State Forester, Director, or whatever his designation, declares when a forest disaster has occurred. He should initiate a salvage plan and coordinate its completion.

Immediately after the storm in Mississippi the State Forester selected a leader in the Forest Industry to be Chairman of a Salvage Council. A Vice Chairman was also selected. Seven days following Hurricane Camille, a Salvage Council with its coordinating committees had been organized and the salvage effort was in gear. The Council was composed of men from different segments of forestry and forestry associations. Assistance to the Council was provided by State and Federal Agencies, forest industries and interested landowners.

To coordinate activities of the group, you may have such committees as: Transportation, Utilization, Information, Inspection, Interest Rates, and Legislation.

During the organizational period an aerial and ground survey will be needed to determine the area and volume damaged. This should be done as quickly as possible.

To facilitate contact between buyers and landowners, preparations should be made whereby one agency, such as your State Forestry Commission, will serve to put buyers in contact with the landowners. This can be done on a county basis. The county office will keep an up-to-date list of all buyers operating in that area and the type of wood they want; then buyers can contact the owners and sale arrangements can be made. The

Extension Service, Soil Conservation Service, and Agricultural Stabilization and Conservation Service can assist in contacting owners, gather the necessary information and funnel it to Commission offices in each county. Absentee owners can also be handled through this office. Many owners, however, will know who the buyers are and will contact them directly.

News releases should be made informing everyone of this service.

Because of increased fire danger it may be necessary to move additional fire crews and equipment into the area -- also additional aerial fire patrols. An accelerated fire danger publicity campaign may be launched along with renewed efforts in law enforcement. Preparations should be made in advance with neighboring states to assist in fire control should the need arise. Some states have such fire compact agreements.

Transportation

Transportation of storm-damaged wood can become a limiting factor. If there is insufficient industry nearby to absorb this wood, then it may entail hauls for some distances. Although industry and contractors move into the storm area from other states to assist in salvage, it may not be enough. Be prepared to call on wood industries to move additional rail transportation out of other sections of the country into the storm area. Yes -- and more train engines may be needed along with planning for quicker switching time. More rail-loading yards may be required, plus equipment to unload and load wood. People will need to be trained to properly load pulpwood cars. Improperly loaded pulpwood will definitely hinder progress. Plans should be made to move in additional trucks to offset rail shortages. If water transportation is available, plan to set up barge landings with facilities to load and handle incoming wood.

You may want to get reduced rail freight rates for hauling storm wood; if so, it may necessitate your working with your Congressional Delegation in Washington, Association of American Railroads and the Interstate Commerce Commission. They were certainly helpful in several aspects of our salvage program in Mississippi.

Plan to work with the Motor Vehicle Section in your State to modify weight limits and licensing of out-of-state trucks; also, your trucks which may be hauling into adjoining states.

Haul routes and weight capacities over rural roads and bridges should be determined to eliminate possible damages and wasted haul time. Your local county government can assist in this matter.

## Marketing and Utilization

Upon completion of the survey, a meeting should be held in or near the disaster area, with invitations going out to landowners in the disaster area, representatives of wood-using industries, timber buyers and producers, foresters (public, industry, and consulting), representatives of railroads and other transportation companies, public land use agencies, financial institutions and other lending agencies, and any others concerned in any way with marketing and utilization of damaged timber.

Requests should be made to utilize as much storm-damaged wood as possible. Industry and landowners in and outside the hurricane area may be requested to curtail cutting undamaged timber in and outside the disaster area and concentrate procurement activities in the storm area. Urge companies to maintain their price structure for damaged wood as before the storm.

Along with removal of weight limits and licensing, encourage buyers to convert purchasing from "weight" to "scale". As in our situation, pine pulpwood began to dry and rapidly lose weight. This will also reduce any tendency to push green wood instead of storm wood.

Advise people to sell their damaged timber as quickly as possible. Small landowners who have an adequate residual stand should keep check on buyers to see that they take only damaged timber. It may be necessary to mark leave trees.

If the situation is such that wood cannot be utilized as it is salvaged, stock-piling should be encouraged. Logs can be placed under sprinkler systems, in ponds or lakes, or sprayed for protection. Pulpwood can be handled in a similar manner. Landowners should be encouraged to haul and sell as much of their wood as possible or cut and move to roadsides to be picked up. In this way they will realize more cash benefits from their sales.

Develop a reporting system to record wood that is salvaged and to keep everyone informed of salvage accomplishments. It may require close cooperation with sawmills to record the volume of logs coming in since damage may be such that some sawtimber will be cut for pulpwood.

Should salvage be expected to last over an extended period of time, then an evaluation of the insect and decay situation should be made to estimate how long storm wood may be salvageable.

## Inspections

You may want to plan to have inspection teams to gather information and data pertaining to the salvage. They can check on the number of rail cars and volumes being shipped, as well as the number of cars needed. Are loading areas getting enough cars? Are there problems in switching at mills and yards?

An inspection team can check if green wood is going out with storm wood; and if so, what percent. They can act on the spot to keep up morale and maintain goals in salvage. Working with transportation, mistakes can be detected, and perhaps, ways found to improve some phases of the salvage program. The team will be in a position to see how badly wood is damaged and what measures have been taken to utilize it. Information, too, can be passed down-the-line about salvage accomplishments, along with suggestions in improvements which have been developed in other areas.

## Information and Publicity

One immediate concern would be to get correct information into the hands of proper people and to inform the public correctly of storm damage and salvage progress. An Information Committee will find splendid cooperation and assistance from the State Forestry Agency, forestry organizations, State Extension Service, industry, and landowners. Of course, the news media is another avenue for distributing information.

Everyone should be informed of possible side-effects, such as, fire and insects. Fire and insect conditions and reports should go out to everyone. Your State Forestry Agency should be in a position to provide this information. Situations or conditions that may hamper or disrupt the salvage effort should be kept to a minimum. Attempt to announce as much positive information as possible and minimize the negative. Feature stories on accomplishments at certain intervals or stages can be encouraging. A story about a small landowner who has completed his salvage can do wonders.

For landowners who may not be aware of a state's responsibilities and abilities, announcements may be required outlining those services which are available. Of course, the services may vary from state to state.

## Summary

The planning for timber salvage following hurricanes will, of course, depend on the magnitude of damage and the availability of local industries. In most areas where such a storm could occur, forestry may

play an important role in the economy. With combined forces of a salvage group operating in a systematic manner, much of the damage can be salvaged. It will call for many additional man-hours of labor -- often on a volunteer basis -- to overcome this potential loss. In the American tradition -- everyone will rally to the cause. We should remember that our forests are a replenishable natural resource; and the quicker we can clean our wounds from a disaster, the sooner we will be back into production.

## PLANNING TO MEET ICE STORM DISASTERS

John E. Graham 1/

In taking a look ahead we need to plan for the occasional forest disaster that occurs because of an ice storm. Apparently most of the southeastern area of the United States is subject to ice storms. Damaged timber can usually be salvaged by normal wood procurement channels.

Occasionally weather conditions become right for a disasterous storm. In South Carolina we have experienced two such storms in the last nine years. One in the lower coastal plain and the other in the upper sandhills section. The storms usually occur between late December and early March. However, we don't know exactly where or when an ice storm will occur. Neither do we know how severe or widespread it might be.

Perhaps we could avoid some of the damage and loss by managing stands with some resistance to ice storm damage. For example, manage tree species most resistant to ice damage at spacings affording maximum protection. However, the most important pre-storm planning will come through a responsible organization with a disaster plan. This organization should represent all of the major forestry interests in the state. It could include related interests such as game and recreation.

In South Carolina we rely on the Foresters' Council. The Council consists of 17 members -- 2 from the State Commission of Forestry, 2 from the South Carolina National Forests, 1 from the Soil Conservation Service, 4 from Clemson University (Agricultural Extension Service 2, Head of the Department of Forestry and a representative from Research), 2 from the pulp and paper industry, 3 from other forest industries, 2 consulting foresters, and 1 from the Southeastern Forest Experiment Station.

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The disaster plan should be specific enough to get the job done but general enough to cover the variableness of forest disasters.

A forest disaster plan for South Carolina was written in 1962. We had a rather severe ice storm in the coastal plain on March 2 of that year. Experiences in coordinating salvage operations following that storm, hurricanes that had occurred in recent years, large fires and pest outbreaks, prompted this action.

Perhaps we can look ahead in ice storm planning by looking back at our recent experiences. I will use the sections of the South Carolina Forest Disaster Plan as an outline for ice storm disaster planning and review the planning and activities that followed our ice storm of February 15 and 16, 1969. A few other possibilities will be included. If additional ideas occur to you, share them with us at the end.

## FOREST DISASTER PLAN

The South Carolina plan is divided into 10 sections.

### Objectives

The first section indicates that the objectives are to recognize the forest resources and the three major types of natural disasters that can severely damage it and to provide for organization to contain the causal agent or salvage damaged timber.

### Participation

### Definition of Forest Disaster

The next two sections state who is to participate and defines a forest disaster.

### Responsibility for Disaster Plan Administration

Administrative responsibility for the disaster plan should be that of the primary public forestry agency in the state. In South Carolina this responsibility is with the State Commission of Forestry through the State Forester with the Foresters Council serving in an advisory capacity.

### Detection of Disaster

Any forestry interest in the state knowing about the disaster plan should notify the administrating agency when a disaster occurs.

When the administrating agency receives this information, it should investigate the suspect area or areas immediately. A meeting of the parent organization responsible for handling forest disasters should be called to determine whether conditions warrant a disaster declaration.

On Monday, February 17, reports of heavy and widespread ice damage came in to the State Forestry Commission's central office from Commission personnel, forest industry personnel, landowners and others.

The State Forester requested his staff to make as detailed a survey of the disaster area as possible in four days to present to the Foresters Council. Coincidentally, a meeting of the Foresters Council had been scheduled before the storm for Friday, February 21.

Survey and Analysis

To determine the magnitude of the disaster and have data to guide salvage plans, a survey and analysis should be made. It would be good to have this information at the time the parent organization first meets. At least some preliminary estimates will be needed. Survey data might include:

1. Delineation of disaster boundaries.
2. Location of heavy, medium and light damage.
3. Salvage volume by products and species (pine or hardwood).
4. Present and anticipated logging conditions.
5. Estimated duration of salvage period.
6. Probable weather conditions during salvage period.
7. Market potential within economic hauling distance of salvage area.

The method of surveying for data would depend upon the nature of storm damage, equipment and personnel available. An aerial survey with ground evaluation is usually best. Very accurate data can be obtained using an operational recorder or photography. The U. S. Forest Service through their Forest Pest Control Division is available to assist in planning and conducting such a survey.

During the week following our storm we made a survey and analysis. Ground crews checked stands to determine extent of damage, volume per acre, species and sizes damaged most. Two aerial crews sketched damage on maps as light, medium or heavy. East-west lines were flown ten miles apart over an 11-county area. From the information the disaster boundary was established and general areas of light, medium and heavy damage were outlined. Estimates were made of the total damage and the potential salvage volume. They indicated that nearly 2 million cords and 40 million board feet of timber were damaged.

## Disaster Declaration

On Friday, February 21, the Foresters Council reviewed the information collected by the Commission of Forestry and received reports from other members. The Council appointed a 5-man Disaster Coordinating Committee to provide for the systematic salvage of forest products in the disaster area. The committee was composed of a representative from the State Commission of Forestry, who also served as chairman, the Extension Forestry Leader, a consulting forester, a pulp and paper company forester and a sawmill representative.

The Extension Forestry Leader prepared an 11-page information kit on ice damage that county agents could use to answer inquiries and advise landowners. It included suggested news articles, a circular letter and information on care of damaged trees. The idea DON'T PANIC, GIVE THE TREES A CHANCE TO RECOVER was prominent along with advice on how to determine which trees should be cut or left. The Extension Forester later provided this kit to all Commission Foresters and others who could use it.

Following the meeting the State Forester declared the existence of a forest disaster in a statewide news release and outlined the extent of damage. This was sent to newspapers, radio stations, television stations and selected magazines that serve the state.

## Salvage Program: Publicity

It is very important that publicity be well coordinated so that factual information is released that will be helpful to people. The general public should be told what happened, where, potential loss and steps being taken to insure maximum salvage. Local news for landowners should keep them informed on how they can get assistance for salvage, market situation, steps being taken to speed or increase salvage capacity.

Rumors will fly so keeping people informed through news media and agency representatives can help correct this. In our case the Commission of Forestry took primary responsibility for publicity with assistance from the Extension Service, especially county agents with local publicity. Here are a few examples:

Friday, February 28, Forestry Commission and Extension Service personnel presented a program on ice damage to timber, shade trees and orchard trees on a local television station. This was a 30-minute evening, prime time program.

Film crews from three television stations covered the March 3 meeting of foresters and county agents to coordinate plans to launch a landowner assistance program. They also filmed salvage operations and used this on their evening news programs. Several newspapers also covered the meeting.

The Forestry Commission sent an illustrated article to a South Carolina farmers' magazine (circulation 40,000) on "What Can I Do About My Ice-Damaged Timber?"

County agents had frequent newspaper and radio releases about the ice storm salvage progress, assistance available, etc.

One county agent arranged a public meeting to hear a situation and progress report and have tax experts to explain federal and state tax laws as they pertain to ice damage losses.

The Commission of Forestry personnel wrote special articles for county unit fire control personnel. These articles stressed the increased fire danger and the need to open up access roads and firebreaks. As you would expect, access becomes a real problem in some places. Main highways may be only partially blocked or soon cleared. Some county roads may be blocked for several days or even weeks.

Salvage Program: Marketing and Production

To get a large salvage job done all potential markets should be explored and the aid of all people in a position to influence salvage success should be solicited. Meetings should be held to present disaster information and discuss proposals for marketing and utilizing the damaged timber. Holding the meetings within the storm damage area may help orient those from outside the area to the seriousness of the problem.

The Disaster Coordinating Committee of the Foresters Council met in the heart of the storm disaster area on Thursday, February 27, and made plans for maximum salvage of damaged timber.

South Carolina wood-using industries were to be asked to concentrate on the disaster area for their wood supply as far as possible, request out of state woodusers to divert as much wood as possible from South Carolina to markets elsewhere, move additional harvest crews and equipment from other areas of the state, and request railroads to furnish an adequate supply of pulpwood cars.

Here are some things that were done to accomplish this. Letters over the Governor's signature were sent to pulp and paper company officials urging their cooperation with the salvage program. Letters over the Governor's signature went to officials of the two railroads that service the area asking their cooperation in furnishing the necessary rolling stock.

The State Forester held a meeting on March 13, to which key forest industry and railroad officials had been invited. The Disaster Coordinating Committee presented the situation, problems, needs and solicited the assistance of those present.

Two of the Commission of Forestry personnel (one was the U&M Forester) were assigned the task of liaison with timber operators. They engineered the securing of pulpwood crews and sawmills from other parts of the state and placing them in the appropriate place in the ice damaged area. They kept a location map of operators and collected salvage data so program progress could be evaluated.

The normal pulpwood production in the disaster area was 2,000 cords per week. Estimation of the capacity of harvest crews and transportation indicated that something over 10,000 cords per week could be expected as a maximum drain. Peak production rose to nearly 13,000 cords a week.

It was apparent that much more timber was damaged than could be utilized before it deteriorated. Therefore, we had to have some guidelines on salvage. We considered around five cords to be the minimum damaged volume per acre to salvage. Actually pulpwood crews approach this figure during normal times now.

Most of the damaged timber was of pulpwood size and since the pulpwood market was flooded we encouraged sawtimber crews to utilize as much small diameter trees (8 to 10 inches d. b. h.) as possible.

The Sand Hills State Forest was in the center of the heavy damage area. It sustained the greatest damage. It was convenient to rail sidings so operators preferred to settle there. To be fair to private landowners we limited operations on the state forest and helped place operators on private lands. The large volumes on the state forest served as a base of operations for producers who were capable of high production. They could work in private tracts nearby.

We also tried to classify salvage chances into areas that should be cut immediately, those that could wait a few months and those that could wait until the emergency salvage period was over. By making this distinction, cutting could be planned to utilize the heavier damaged stands first.

During part of the salvage period local quotas kept some crews working only two or three days. In such a situation where the wood might be lost and labor is available there is a possibility of storing wood for future use. However, an investor would have to be located and the storage facilities constructed. Roundwood storage could be provided in ponds if the value of the product can justify the double handling and recovery from the pond. A better prospect is the temporary plastic storage building patented by Union Camp. It is believed that wood can be stored up to three years without appreciable deterioration in these inexpensive structures. Temporary yards could be prepared for storing sawtimber.

The Extension Service was to act as clearing house for requests for assistance and make office space available for foresters where possible. They were to keep other agricultural agencies advised and assist with general publicity.

The Forestry Commission was to provide foresters to assist landowners with "on-the-ground" advice including sales assistance, hold landowner meetings to launch program with Extension Service and issue publicity.

On March 3, a meeting was held in the disaster area to acquaint county agents and Commission of Forestry personnel with the assistance program. This provided a chance to view various types of damage and how each should be handled. Nine management foresters from other parts of the state worked in the ice damage area during the next six weeks. They usually worked two to three days per week. Also the eight local foresters concentrated on the storm damage salvage project.

Most requests came into the county agent's office and were recorded on a TIMBER SALVAGE REPORT form (duplicate or triplicate if county agent wanted a copy). Information on how, where and when to contact the landowner was entered.

Foresters examined the damaged woodlands and advised the owner where, if any, cutting was needed and when it should be done. He provided a list of buyers and discussed the market conditions. He filled in volume and acreage figures on the TIMBER SALVAGE REPORT. If the landowner wanted the forester to contact a buyer, a TIMBER SALVAGE REFERRAL form was completed. A copy of these reports was given to the U&M Forester to use for his records and to place timber operators.

Through June, Foresters had provided assistance to more than 600 landowners.

1. 211 of these owners had operable amounts damaged.
2. 160 had either cut their timber or had made arrangements for salvage.
3. 51 landowners needed additional help.
4. 75 landowners had light to medium damage that was to be marked later for thinning.

It was estimated that more than 200 owners made direct contact with producers and dealers and salvaged their damaged timber. Consulting foresters had assisted a number of large landowners with salvage.

Salvage Program: Records

Records are difficult to get from producers. There were so many different operations in many different locations. Some method of collecting or reporting drain data is needed. We canvassed operators periodically for volumes cut.

Secondary Effects

Landowners and foresters should be alert to secondary effects, especially insects. The Division of Forest Pest Control, U.S. Forest Service, was very helpful to us in setting up a bark beetle study project. We established 65 observation plots in the counties where most of the damage occurred. The plots were checked every two weeks. Bark beetles, especially *Ips grandicollis* and *calligraphus* built to high populations, but by October they had diminished. We made an aerial reconnaissance of the area in August and observed few spots of mortality. However, we will still need to observe the disaster area during 1970 to make final judgment on the influence of bark beetles. A problem may develop in hardwoods from rot and sprouting along the lower part of the main stem.

Declare Disaster Over

When the ice storm salvage program is completed, the administrating agency should issue an appropriate news release declaring the disaster over and giving pertinent facts about the program. Our initial emergency salvage is complete and the disaster will be declared over in March.

More than 200,000 cords of pulpwood and 10 million bd. ft. of sawtimber have been salvaged.

There are a lot of hardwoods damaged so badly that salvage may be required in the next few years.

Where an ice storm involves two states, there should be communication between them regarding their problems and plans. Shortly after our storm contact was made between salvage planners in North Carolina and South Carolina.

Planning for subsequent ice storm disasters should be easier if we keep good records and share our experiences in work conferences such as this one.

## CONTROL OF WOOD PRODUCTS INSECTS

H. R. Johnston [1/]

Insects of many species damage wood in logs, pulpwood, and stored lumber, as well as in finished wood products. The annual monetary loss caused by these insects is not known, but it is certainly very great. The annual loss caused by subterranean termites alone has been estimated at $400 to $500 million in the United States. Most probably the national loss caused by all wood products insects is well over one-half billion dollars per year. The Southeast absorbs much of this loss because its temperate climate favors insect activity.

For convenience, the discussion of damage caused by and control of wood products insects is divided by product into protection of logs and pulpwood, lumber on drying yards, and wood in use. In keeping with the theme of this work conference, "A Look Ahead", the protection outlook is discussed.

### LOGS AND PULPWOOD

Ips bark beetles cause considerable damage to pine saw logs and pulpwood. Although these beetles do not bore into the wood, their entrance holes through the bark allow rapid entry of decay organisms which hasten deterioration.

Both hardwood and pine logs are damaged by several species of ambrosia beetles and by long-horned borers. In their small tunnels, ambrosia beetles cultivate stain and decay fungi that are then eaten. Both the holes and the fungi degrade lumber and plywood obtained from the logs. The principal damage caused by a long-horned borer is the tunnel itself. These insects are a problem when logs or pulpwood must be stored for

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several weeks or more. Damage is acute after disasters such as windstorms, ice storms, floods, or fires that kill abnormal quantities of timber.

Rapid utilization of pine and hardwood logs will eliminate or greatly reduce the losses caused by insects, and chipping solves the problem of millyard storage of pulpwood. Neither procedure is always possible, however, particularly in disaster cases.

Probably the best method known for protecting pine and hardwood logs from insect damage is to keep them wet. Storage of logs in water will protect the portions covered by water, but not the parts above water, Furthermore, handling costs make this method expensive. Continuous spraying with water, however, is both cheap and effective. The spraying system may include overhead pipes and nozzles or simply perforated water hoses laid across the log beds. The essential requirement is that the surface of the logs be kept thoroughly wet.

In the past, hardwood and pine logs have been protected from insects for several months by thoroughly spraying them with 0.5 percent gamma isomer of benzene hexachloride in No. 2 fuel oil. Some pulpwood has been protected by dipping it in a water emulsion consisting of 0.25 percent gamma BHC.

## LUMBER ON DRYING YARDS

In drying yards, green hardwood lumber of many tree species is sometimes damaged by ambrosia beetles, and lyctus beetles damage such species as oak, hickory, and ash after the lumber has dried to about 30 percent moisture content. The damage caused by these insects on drying yards can be prevented by dipping the lumber at the green chains in a water emulsion containing 0.1 percent gamma BHC. This chemical is compatible with the chemicals commonly used to prevent blue stain in lumber. Since the insecticide remains on the surface of the lumber, retreatment is necessary if the material is planed and stored again.

## WOOD IN USE

The most expensive form of insect damage to wood is that to material in use, because the entire investment in manufacturing and installation is threatened. Chief among the insects that cause such damage are subterranean termites. Other troublesome insects include various species of powder-post beetles, especially lyctus and anobiids, and drywood termites. Well-seasoned hardwood and pine lumber, both in storage and in use, is subject to attack by powder-post beetles.

Much of the damage to buildings by subterranean termites could be prevented if homeowners, architects, and contractors would take greater precaution during design and construction. Some preventive measures include -- removing wood debris from the building site, assuring drainage away from the site, making foundations impervious to termites, providing proper ventilation, and applying insecticides to the soil under and around foundations. The insecticides, 0.5 percent of either aldrin, dieldrin, or heptachlor or 1.0 percent chlordane, in water emulsions, are especially useful in treating the soil before pouring concrete slab foundations. These formulations are also effective in controlling active infestations of termites when applied to the soil around or under existing foundations.

To control small easy-to-reach infestations of powder-post beetles in buildings, thoroughly spray or brush the infested parts, such as pine sills and joists or hardwood flooring, with either 0.5 percent dieldrin, 0.5 percent lindane, or 2.0 percent chlordane in a solvent such as mineral spirits or kerosene. In large timbers with deep-seated infestations, more than one application may be necessary. If the infestation is widespread, fumigation is advisable. Drywood termites, which are a problem in southern Florida, can be controlled by the same methods as powder-post beetles.

## FUTURE OUTLOOK

Although somewhat satisfactory measures are available for protecting logs and pulpwood from insect attack, improvements are possible. Where water spraying is not feasible, a chemical is needed that is less toxic than BHC; future research should be aimed at finding such a chemical. Also, we should not forget the possibility of biological control if funds become available for study of the insects that attack logs and pulpwood. Nationwide, the losses caused by these insects are far less than the losses caused by subterranean termites and powder-post beetles. Hence, research in the near future will be on the latter two groups.

Studies are now in progress on the nutritional requirements of lyctus powder-post beetles; the objective is to find an essential constituent of the diet that can be removed from the wood, making it unsuitable for the insects. Similar work may be undertaken for anobiid powder-post beetles. It is possible, for example, that continuous spraying of water on logs may remove constituents essential to powder-post beetles. At present and probably for some time to come, however, we will have to rely on chemical control of these beetles. Research is needed to find a chemical that gives good control on lumber in storage and in buildings but is less toxic than BHC and other chlorinated hydrocarbons. Investigations are in progress on the biologies of the anobiids to find a weakness that can be used in biological control.

At present there are no satisfactory substitutes for the insecticides aldrin, chlordane, dieldrin, and heptachlor in control of subterranean termites. Banning use of these chemicals, therefore, would put control work back where it was 20 years ago. We might find ourselves treating soil with such chemicals as coal-tar creosote and sodium arsenite, which are more expensive and much less effective than the so-called hard insecticides. Although we have never stopped searching for chemicals that will give long-term protection against termites but be less harmful to beneficial organisms, such work will be intensified. Underground baits of wood treated with the insecticide mirex show promise as a control for subterranean termites. Studies are underway to find attractants and bits of information on termite biology that may be useful for control.

## PESTICIDES PRECAUTION STATEMENT - 1

(For use in USDA publications on pest control on the farm and in the forest.)

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key -- out of the reach of children and animals -- and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

## PESTICIDES PRECAUTION STATEMENT - 2

(For use in USDA publications on pest control in the home, yard or garden.)

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers -- out of reach of children and pets -- and away from foodstuff.

Apply pesticides selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. Avoid prolonged inhalation of a pesticide spray or dust. When applying a pesticide it is advisable that you be fully clothed.

After handling a pesticide, do not eat, drink or smoke until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If the pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Dispose of empty pesticide containers by wrapping them in several layers of newspaper and placing them in your trash can.

It is difficult to remove all traces of a herbicide (weed killer) from equipment. Therefore, to prevent injury to desirable plants do not use the same equipment for insecticides and fungicides that you use for a herbicide.

NOTE: Registrations of pesticides are under constant review by the U. S. Department of Agriculture. Use only pesticides that bear the USDA registration number and carry directions for home and garden use.

# PEST CONTROL IN URBAN AREAS IN THE FUTURE

John W. Mixon 1/

Many of you see Atlanta from the window of an aircraft circling the Atlanta Airport. You see our beautiful city of big buildings, our golden dome, and our expressway systems.

As forest entomologists, I'm sure you notice that Metropolitan Atlanta is covered with trees. Atlanta is the city of trees; sixty-four percent of the 2,000 square miles that make up Metropolitan Atlanta may be classified as forest land. However, more and more we find homes under these trees. We have approximately 425,000 housing units occupied by 1.3 million people. People are coming to Atlanta at the rate of 125 families per week. Keeping this in mind it is easy to see that we are going to have increased interest in trees in urban areas.

Before we discuss pest control in the future, let's look at some of the many problems we face today. Our problems in the larger cities are the same as yours in smaller areas. We just have more of the same.

Diseases such as fusiform rust and powdery mildew are a constant scare to the city dweller as to any shade tree owner. Mechanical damage is probably our number one problem in Metropolitan Atlanta. Naturally this encourages insect attack such as the bark beetles in pines; Pine bark beetles give us much activity each year. Leaf minors which cause little problems to forest trees always cause great alarm to the shade tree owners.

The tree borers such as dogwood borers, ambrosia beetles and others cause much concern. Leaf feeders as the bagworms, elm leaf beetles, tent caterpillars, orange-striped oak worms have the owners calling our metro foresters and entomologists in the area.

Scale insects, aphids, leafhoppers really are recognized when they cover a desirable tree over the patio or over the driveway. We cannot leave our friend, the Elm Bark Beetle out of the picture who has created much attention since 1965. We receive many calls on a two legged insect. As you know this is the yellow bellied sapsucker which many people think to be a pine borer.

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1/ Metro Forester, Georgia Forestry Commission, Atlanta, Georgia

These are just a few of the insect problems we are called on to diagnose in Metropolitan Atlanta. What about the future? I feel that a stepped-up educational program for the tree owner is going to be one of our greatest assets. There is no way to improve on-the-ground assistance for tree owners on an individual basis. Our Metro Foresters have answered 2,837 requests during the past 30 months in this manner -- we must use T.V., radio and newspaper articles to get the message to the people. Our foresters have presented 59 T.V. programs and 22 radio programs and published 246 news articles. We have our own cameraman who assists us in making T.V. films for our weekly Metropolitan Forestry Program.

We need good, but simple literature to notify the general public of problems such as the Dutch Elm Disease. You may say: "It sounds good, but it won't work". I think it will work. You and other researchers are going to come up with safe systemics for the urban homeowner. I feel that hydraulic and mist sprayer applications of insecticide are on the way out. With home lots selling from $5,000 to $30,000 the owners are definitely interested in the trees on those lots. If they are interested in the trees, you know they are interested in the pests that are destroying these trees.

We have a big job in working with the various arborists. These men are not specialists in insect diagnosis as you are. They need more training in insect control. The Georgia Forestry Commission and the Atlanta Parks Department started a Metropolitan Atlanta Shade Tree Workshop four years ago. Approximately 100 people were in attendance each year. The ladies Chamber of Commerce, the Garden Club of Georgia, the U.S. Forest Service and the Commercial Arborists and other groups were asked to participate. We must set up more workshops for the average homeowner.

Good displays and exhibits on insect control should be displayed in every area possible. The City Parks Department has a portable display of live insects, made by the city entomologist, which is very good. I have seen people standing in line to see this display.

We need to combine our efforts in urban pest control. The Atlanta Arborist Association was formed recently by the Georgia Forestry Commission and the Atlanta Parks Department. Presently we have 48 members from the Arborist profession, the Metro Foresters and the City Parks Department. We need more of you in Atlanta to become members. Other cities have similar organizations that you non-natives should join.

In summary, I feel that we have done a good job in the laboratories and in the field on our control programs; but, we have fallen short in informing the public. DDT is a fine example -- many people are opposed to DDT when they know very little about the insecticide. In the future, we must inform our urban tree owners of the pests which will harm their trees and how to control them or who to contact for control on a professional basis. Television, radio, newspapers, displays and good simple information leaflets are going to be our answer.

## PANEL ON FOREST DISEASES


Panel on Forest Diseases - L to R, R. D. Wolfe, Pathologist, Zone 2, Alexandria, Louisiana; F. J. Czabator, Pathologist, Southern Forest Experiment Station, Gulfport, Mississippi; C. S. Hodges, Pathologist, Southeastern Forest Experiment Station, Research Triangle Park, North Carolina; E. R. Roth, Pathologist, Area Office, Atlanta, Georgia; W. R. Phelps, (Moderator), Pathologist, Area Office, Atlanta, Georgia.

# TREE RESISTANCE TO INSECTS AND DISEASES

E. R. Roth [1/]

It has been estimated that 40 percent of the annual increment of forest trees is lost to insects and diseases in the South each year. Our present direct control techniques are expensive, temporary and inadequate in that we are unable to change the conditions that caused the epidemics to develop in the first place.

I would like to suggest that what we need to do is give greater emphasis to the development and use of resistant varieties of forest trees. Are the results and leads obtained from past experience, both with row crops and with trees, promising enough to warrant a change in emphasis in the control field?

Probably the most effective and ideal method of combating insects and diseases that attack plants is to grow resistant varieties. What is an insect or disease resistant plant? A plant has a degree of resistance if it sustains less damage at a given level of infestation than the average of other plants grown in the same environment.

How is a resistant variety obtained? Scientists use three general methods. (1) They introduce a variety that through natural selection already possesses a higher than usual level of resistance to a given pest. (2) They expose plants of a given variety to pests and select the resistant individual plants for propagation. (3) They hybridize plants to transfer the demonstrated resistant characteristics to desirable varieties. There is a need for an increased emphasis in forestry research for resistance to forest insects and diseases.

"Nature has been breeding disease resistant plants since the world began." Resistance is more or less "a survival of the fittest".

If we look at resistance from one point of view, we see that any plant is resistant to most insects and diseases. We know that any plant growing in nature is open to attack by spores of numerous fungi and many species of insects. Resistance is the law of nature and susceptibility is the rare exception. In our early American forestry, we worked in opposition to improvement in that we harvested the best and left the worst.

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Why haven't we had more advocates of resistance in the past? Many foresters decided against it because of the initial cost and the time required to develop resistant strains. We need to keep in mind that the only cost is the original cost of developing the variety. If we get resistance we save the annual loss from the insect or the disease, the cost of chemicals, and resistance will probably last for many years.

Let us consider the cost of research in developing plants resistant to four insects, the Hessian fly, the wheat stem sawfly, the alfalfa aphid and the European corn borer as compared to the estimated value. This work took 462 man years at $20,000 per year or about 9.3 million dollars. The savings to the farmer are estimated at $308 million per year. Most resistance of this type will last a minimum of ten years or a total saving of $3 billion or a 300 to 1 return for each research dollar invested. How can we afford not to develop resistant trees?

The first serious consideration of resistance to forest pests in America was when pathologists realized that they were not able to control the spread of chestnut blight. If we observe an epidemic, we can see that variations exist as to the time that trees are attacked and the time it takes for the trees to die. What is the mechanism or basis of resistance or immunity in plants and what are the advantages and disadvantages? In working with forest trees we have the disadvantage of time required for each generation but we have the advantage of ability for vegetative reproduction.

What are some of the limitations of developing a resistant variety?

1. There may not be a source of resistant genes.
2. It may be difficult to combine resistance with other desirable characteristics.
3. Hybrids may be cross-fertilized by close planting and then become genetically contaminated.

Plants may be resistant or immune to insects or diseases because of mechanical, chemical or functional defenses. As a general rule, the defense mechanism of a plant does not depend on any one structure, product or function but is a combination of several. If any of the combination of factors is missing then the plant is susceptible.

By observing trees, we find that not all trees of one species have the same gross characteristics. We find differences in branching, length of needles, size of leaves, thickness of bark, etc., or we can say we find variation within the species. It follows that trees vary in their ability to transmit resistance to their progeny and it is not always

possible to predict resistance characteristics based on resistance of parents. In plant breeding it is often necessary to have interspecific crosses and backcrosses in order to incorporate all sources of resistance.

Since differences do appear in natural populations and since intraspecific and interspecific crosses may result in progenies with improved resistance we may inquire just how is insect and disease resistance in trees controlled. Resistance could be controlled by a single dominant gene where the progeny of an interspecific cross would be 100 percent resistant and a backcross on the susceptible parent would be 50 percent resistant and 50 percent susceptible. We may have minor gene resistance where selected trees would yield progenies with a higher percentage of resistant individuals than would crosses of unselected material.

A tree may show resistance prior to pathogen attack or some factors may develop as a response to pathogen attack. Those factors that are associated with the trees prior to attack are called pre-penetration factors and those that develop as a response to attack may be called post-penetration factors. The pre-penetration factors are mostly anatomical such as size of lenticels, leaf hairs, foliar habit, needle age, sucrose content, tannin type, moisture content, time of year and saprophytic microflora. The post-penetration factors develop after the tissues have been penetrated and include such things as wound periderm and tyloses.

Reliable examples of true insect resistance are scarce. Painter breaks down the resistance of insects into three categories.

1. Host preference -- After nearly half a century forest entomologists still know little about how Dendroctonus bark beetles select trees to attack. Do initial attacks occur at random or as a response to some stimuli?

2. Tolerance -- Tolerance refers to the ability of a tree to repair insect injury or grow despite insect attacks.

3. Antibiosis -- Antibiosis refers to the injury or destruction of insects by the host. For example, in some coniferous species that are non host to Dendroctonus bark beetles, the first pitch flow is toxic to and kills the beetles.

There is evidence that some species are resistant in the cotyledon stage and become more susceptible as they become older. It would be of little value to select seedlings resistant to insect and disease attack if they

became susceptible in the plantation. In the field shortleaf pine is resistant to littleleaf for about 20 years and then become susceptible.

The absence of a disease or insect does not necessarily give proof of resistance.

Today we stand where crop resistance breeders stood a half century ago. Because of the public clamor against the widespread use of pesticides, air and water pollution, it is imperative that we develop pest resistant trees.

Why are some trees not attractive to insects?

1. Lack of specific chemical attractants, i.e., flavors and odors.
2. Presence of repellent distasteful or masking flavors and odors.
3. Unsuitable surface textures - roughened, smooth or hairy.
4. Physical barriers - tough or thickened cuticle or other overlaying layers, resin ducts or resin exudations.

For insects attacking forest trees, there is evidence of resistance to bark beetles, weevils, pitch midge, locust borer, Dioryctria spp., European pine shoot moth and pine tip moth.

For bark beetles, host specificity is one manifestation of resistance. In referring to Dendroctonus and pine, we think of the successful attack of one beetle species to one or more pine species. Experiments have demonstrated that host specificity of Dendroctonus species disappears if the host pines are not living. Some feature of the living tree enables it to resist attacks of certain species of Dendroctonus. It would seem that perhaps each bark beetle species has a relatively high tolerance for turpentine compounds found in the pine species it normally attacks. When relative tolerances for turpentine compounds have been established for each species of Dendroctonus, then geneticists will be able to produce beetle resistant pines as species have highly heritable and specific characteristic turpentine constituents.

The gouty pitch midge prefers trees with shoots that have sticky, resinous surfaces. Shoots that are dry and smooth or covered with a waxy bloom show resistance to the midge.

Certain varieties of locust have shown resistance to the locust borer. Some individual pine trees in a study conducted by Merkel showed below average attacks by Dioryctria.

Crosses of pine have been made and classified according to their resistance to tip moth attack. It would appear that through interspecific crosses hybrids can be produced that will reduce tip moth damage to a tolerable level.

The greatest research effort in the South for resistance to a forest disease is concentrated on fusiform rust of southern pines. The main purpose of research into resistance of southern pines to fusiform rust is to evaluate resistance in the susceptible species and to attempt to incorporate by interspecific crosses the resistance assumed for shortleaf. Interspecific crosses of longleaf X slash and shortleaf X loblolly have been tested. These hybrids are not immune but do show resistance. Even though work on resistance of slash and loblolly has been going on for a number of years, there is still much to be done.

Pathologists have been working on resistance to blister rust for a number of years. Hybridization of white pines, notably production of hybrids between North American white pines and Eurasian white pines, known to display resistance to blister rust indicate that blister rust resistance is a heritable trait. Some pines have been developed that are resistant to blister rust but do not have desirable tree form.

Juvenile longleaf pines vary considerably in their susceptibility to brown spot needle blight. Under similar exposure, a few seedlings may prove resistant while the rest are heavily attacked and eventually die. The extent to which resistance is genetically controlled has not been determined. Progeny from an apparently resistant tree discovered by Siggers and planted on the Palustris Experimental Forest near Alexandria, Louisiana, demonstrated resistance to brown spot disease.

In 1955, Zak reported that one parent progeny from selected shortleaf pines indicated definite inheritance of resistance to littleleaf. Individual healthy trees are often observed surviving among dead and dying trees in stands severely affected with littleleaf. In inoculation tests with progeny from apparently resistant trees, resistance broke down under severe condition tests; however, evidence of inherited resistance has been demonstrated both with respect to adverse soil conditions plus *Phytopthora cinnamoni* and to *P. cinnamoni* alone.

The American chestnut appears to be completely susceptible to the blight so we had to have large scale introductions of blight resistant chestnuts from the Orient for an effective breeding program. In 1947-55 J. D. Diller established chestnut and hybrid chestnut test plots in the eastern U.S. One of these hybrids growing near Cartersville, Illinois seems to

be the most promising hybrid to date. Its parents are Chinese X American backcrossed on American. At 21 years of age, one of these hybrids was 11. 3 d. b. h. and 63 feet in height. It shows so much promise that it has been named the "Clapper Chestnut" after its originator. The above tree in 1969 was showing some symptoms of blight. Studies of the tannin of Chestnut suggest that the relative susceptibility of Chinese, Japanese and American chestnut is the result of the differential solubility and qualitative differences among the tannins in the three species studied.

European investigators have found two selections of the smooth-leaved elm, the Christine Buisman and the Bea Schwartz that are resistant to Dutch elm disease. The Christine Buisman has been tested and released in the U. S. and is now available at commercial nurseries.

Drs. Hepting and Toole obtained wilt resistant mimosa trees by selection and vegetative propagation.

Where do we go in the future? What appears to be the best avenues to follow? The pathologist, entomologist, geneticist and physiologist should all work together in solving problems. We have a tendency to follow the lines of least resistance, for example if bark beetle attacks occur where there is flooding we blame the attack on flooding. On the other hand if the attack occurs in a droughty area, we blame it on dry weather. Why don't we consider the difference in chemical make-up between trees in hot spots and those where attacks seldom occur. What is the difference in chemical make-up between a preferred host and one seldom attacked? Why does blister rust attack only five needled pines? Why doesn't fusiform rust infect shortleaf and Virginia pine in the same degree that it infects loblolly and slash? Why does cone rust infect slash and longleaf and not loblolly? If we knew the answers to the above and similar questions, our knowledge of resistance would be much further advanced. There is indication that bark beetles are subject to toxicity of rosin and volatile turpentine in species that are not preferred hosts, poplars susceptible to leaf rust have more glucose in relation to reducing sugars in their make up, and in chestnut the tannins from the bark of the Chinese chestnut are more toxic to the chestnut blight fungus. Volatile turpentine constituents inhibit the growth of some wood inhabiting fungi including Fomes annosus. From these leads, it would appear that the most fertile field for research would be either in analyzing the chemical content of resistant and susceptible species or in establishing tolerances for the insect or fungus species.

Instead of saying this or that species is resistant or susceptible we need to inquire as to why it is resistant or susceptible. We need to increase our efforts in developing insect and disease resistant trees.

In our current society anything that decreases the use of pesticides is popular because of the health aspects, likewise decreases in the use of pesticides will increase the quality of our environment. Some of you may live to see slash pine resistant to fusiform rust cankers; pine trees resistant to beetle attacks, the possibilities are there, all we need is for someone to find the right combination.

## THE CURRENT STATUS OF ANNOSUS ROOT ROT IN THE SOUTH

Charles S. Hodges [1]

*Fomes annosus* (Fr.) Karst, was first collected in the southern United States from a pine log in Alabama in 1887 (12). It was first reported as a pathogen on white pine in North Carolina in 1923. Subsequently, the fungus has been found on all the major southern pines as well as eastern redcedar, Atlantic white cedar and Frazer fir. The most important hosts; however, are slash and loblolly pines.

Current losses from annosus root rot are unknown. The only southwide survey for this disease was conducted in 1960 (9). At that time, the disease was found in 59 percent of thinned plantations of loblolly and 44 percent of thinned slash pine plantations. Overall-losses were light; however, with only 2.8 percent of the loblolly and 2.2 percent of slash pines killed or infected. The potential threat of the disease on hazardous sites is more serious. Driver and Dell (1) reported that mortality in one 22-year-old slash pine stand, with a volume of 30 cords per acre of standing timber, amounted to 12 cords per acre in the first five years after thinning. An additional 7 cords per acre showed symptoms of the disease.

In a recent survey in east Texas by Mason (7), 75 percent of all thinned plantations were infected and *F. annosus* was present in 96 percent of those plantations which had been thinned more than 3 years previously. Sixty-three percent of slash pine and 37 percent of the loblolly pine plantations were infected. Mason gave no information in this report on mortality, however. The current situation for the South as a whole, however, probably lies somewhere between the data recorded in the 1960 survey and that just found in east Texas. Unless timber management practices

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are not drastically changed, there is no reason to believe that the average mortality from annosus root rot will increase over the relatively low levels indicated by the 1960 survey. The total losses, however, can be expected to increase significantly because most of the plantations established in the past 20 years have not yet been thinned and thus not yet exposed to infection.

In my remaining time, I would like to briefly review the current status of major areas of research on F. annosus being conducted by Forest Service and other scientists in the South. Some of this will be "old hat" to many of you, but it is difficult to discuss new findings without reference to earlier results which prompted the current research.

Although F. annosus has been studied for more than 150 years, it was not until 1951 in England (10) that Rishbeth discovered the role of the freshly cut stump surface in the infection biology of the fungus. He found that spores of the fungus are carried from their source, the fruiting body or conk, to freshly cut stump surfaces where they germinate. The fungus grows through the stump and into its root system, and spreads to adjacent healthy trees at points of root contacts or grafts. Numerous workers in all areas of the world where F. annosus is a problem have since substantiated Rishbeth's findings, and the stump surface is considered the major point of entry of F. annosus into a previously healthy stand.

Knowledge of the existence of this infection court has generated considerable research, primarily on ways to prevent the stump from becoming infected. This included work on the fungus itself as well as the host-fungus relationship.

Since the pioneering work of Rishbeth, numerous workers have tested various chemicals for preventing stump infection by F. annosus. Of those that have been tested, only three are still recommended. Sodium nitrite, applied as a 10 percent solution, is used in England and Canada. It appears to be effective, but it is highly corrosive, toxic in large quantities, and cannot be used around water reservoirs. A 20 percent solution of urea has been found effective in several trials in the central and northeastern United States, Dry granular borax, sprinkled "salt-shaker" style onto the stump surface is currently recommended for stump treatment in the South. This material gives excellent protection to the stump surface and is easy to apply, cheap, and safe to use. It is the only chemical registered by the USDA for use in controlling F. annosus. Borax,as well as the other chemicals, must be applied immediately after felling.

I am aware of two cases in which some mortality from F. annosus occurred in the residual stand several years after stumps were treated with borax. One explanation for this is that the stump roots were infected directly by spores which filtered down through the soil. This method of infection is known to occur in some soils (3) but is not believed to be nearly as important as stump-surface infection. Another possible explanation is that infection took place through logging wounds around the root collar area. Recent work by Koenigs (5) has shown that protective amounts of borax do not diffuse more than 2 inches from the stump surface; therefore, wounds below this point are susceptible to infection by airborne spores.

One disadvantage of borax is that it prevents stump colonization by competitive microorganisms as well as by F. annosus. For this reason, it should never be used to treat stumps in plantations where F. annosus is already present. Because lack of competition by airborne microorganisms allows unimpeded growth of F. annosus, stumps of trees lightly infected before felling are rapidly colonized by this fungus.

Another stump treatment commonly used in England and which has shown promise in the South is inoculation with the fungus Peniophora gigantea. This fungus is a common slash decayer found in many parts of the world. Peniophora grows considerably faster than F. annosus in the stump. It not only prevents stump infection by F. annosus, it can replace F. annosus under certain conditions. In fact, it is probably responsible for considerable biological control of F. annosus under natural conditions. Major disadvantages in its use are problems in the production and storage of spores for inoculum and the necessity of using sprays for inoculation. Scientists at Duke University are now studying ways to increase the natural inoculum in the field. We are also hoping to develop a device on mechanical tree harvesters which would automatically spray stumps with inoculum. Peniophora would be a good choice for stump treatment in stands where F. annosus is already present.

Most of you are aware of the work which has been done with summer thinning to reduce stump infection by F. annosus. Preliminary data in a study conducted several years ago at Bainbridge, Georgia, by Ross (11) showed that few or no stumps were infected between March and September. Recent assessment of this study after 5 years showed that residual tree mortality corresponded directly to the percentage of infected stumps found shortly after felling. A similar study conducted near Aulander, North Carolina showed that the period of low stump infection occurred only during June, July, and August. Two factors are responsible for lower stump infection during the summer. First, the temperature at the stump surface reaches levels lethal to spores and mycelium

of F. annosus. Secondly, the fungus produces few, if any spores during this period. The shorter period of stump susceptibility at Bainbridge reflects both these factors.

Recently pathologists of Division of Forest Pest Control at Asheville, North Carolina and Pineville, Louisiana, in cooperation with research pathologists on the Annosus Root Rot Project, established a pilot test to evaluate most of the presently recommended control practices for F. annosus. These included stump treatment with borax, sodium nitrite, and Peniophora gigantea and summer thinning. Three plots were established in each of three arbitrarily chosen zones of latitude across the southern United States.

It has long been known that soil characteristics influence the rate of spread of F. annosus through stands where stumps are infected, although the actual infection of the stump itself is unrelated to soil characteristics. In the Gulf States, Froelich, Dell, and Walkinshaw (2) showed that F. annosus developed most rapidly on areas characterized by combinations of lower organic matter, higher pH, higher sand or clay content and heavier grass cover. Morris and Frazier (8), in developing a soil hazard rating for Virginia forests, found that texture and depth of the A horizon and depth of the water table significantly influenced the rate of development of F. annosus. Sandy loams and loamy sands were the most hazardous sites while silt loams and clay loams were less prone to infection. Light soils where the A horizon was less than 8 to 12 inches deep were less hazardous than soils with A horizons more than 12 inches deep. Soils with high water tables or mottling at 18 inches or less were classified as low hazard sites.

Eldon Ross (Forestry Sciences Lab., Athens, Georgia) and I have established spread plots on several kinds of sites in the Piedmont and Coastal Plain of the Southeast. Spread from the plot centers has varied from 6 to 12 feet to more than 30 feet in 5 years. We are now collecting detailed soil data from these plots. When these data are analyzed they will give us additional information on the influence of soil characteristics on rate of spread of F. annosus and hopefully will lead to a hazard rating system for southern soils.

In the study of Froelich, Dell and Walkinshaw mentioned previously, grass cover was one of the factors correlated with lower incidence of F. annosus. Because grass development in forest stands is usually dependent on fire to remove heavy accumulations of litter, Froelich established a number of test areas to study the influence on F. annosus of prescribed burning prior to thinning. Preliminary results were somewhat encouraging and a much larger study was recently established on plots located from Texas to Georgia.

Little research has been conducted on the relative interspecific and intraspecific susceptibility to F. annosus. Recently Kuhlman (6) perfected a seedling inoculation technique which allowed him to screen a large number of seedlings for relative susceptibility to F. annosus. Using this technique, he showed considerable variation in symptom expression among nursery-run seedlings and some variation in susceptibility among species of southern pines. These studies indicate that some resistance to F. annosus may be present in southern pines. A more recent study just concluded by Kuhlman, using progeny from controlled pollinated loblolly pine furnished by cooperators in the N. C. State Tree Improvement Program, seems to corroborate this. A number of families from five geographic locations in the South were screened. Average mortality ranged from 81 percent for families from Alabama Piedmont sources to 45 percent for families from the North Carolina and Virginia Coastal Plain sources. Mortality within individual families ranged from 13 to 100 percent. Most importantly, in several instances a parent produced two or three families that were more resistant to F. annosus than were related half-sib families by a different parent. This indicates that resistance to mortality, at least in seedlings, is genetically controlled. This study is now being repeated with additional families.

Two years ago, I began a study to determine the relative susceptibility of loblolly, slash and longleaf pines of thinning age to F. annosus (4). On the basis of root inoculations, the percentage infection was 86 for loblolly, 70 for slash, and 11 for longleaf pines. Average rate of growth of the fungus in infected roots was 8.3, 6.3 and 2.3 inches, respectively. A similar study set up last year showed that, although percentage of infection was much lower than in the previous test, the relative susceptibility was the same. Infection centers also were established in plantations of each species to study the rate of spread in the stand.

A problem faced by many land managers is what to do with stands so heavily infected with F. annosus that they must be clearcut. European experience on this problem has shown that F. annosus increases in severity in each succeeding generation and that more or less impractical methods such as stump removal are necessary to produce relatively disease-free new stands. A number of replant experiments have been established in the South by federal, university and industry researchers. In general the results of these studies show that losses have not exceeded much more than 1 percent per year during the 5 or 6 years the studies have been in progress. Only time will tell if these losses continue and if replanting infested sites will indeed be a problem in the South. One advantage the South has is that F. annosus does not remain active in the stump as long under southern conditions as it does in Europe and other parts of the United States. The fungus usually disappears from stumps in less than 10 years compared to survival of 20 or more years in Europe.

The subjects I have covered today deal more or less directly with control of F. annosus. There are many other aspects of the problem which would require much more time to consider. In summary, F. annosus currently is found in the majority of the thinned slash and loblolly pine plantations in the South, but average losses are relatively low. The average mortality contributable to annosus root rot is expected to remain relatively low, but overall losses will increase as more and more plantations are thinned. I believe that we can recommend stump treatment and summer thinning as practical and presently available measures for control of F. annosus. It is hoped that prescribed burning, site hazard ratings and resistant lines can be added to our arsenal in the near future when these have been more adequately studied.

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## PREVENTING PINE DISEASES

Felix J. Czabator 1/

There are only three diseases of pine which are of practical importance in the southern forest, in terms of wide distribution and total impact on productivity. These are fusiform rust, brown-spot needle blight, and annosus root rot. The other known diseases, such as littleleaf, needle cast, Commandra rust, etc., are either of sporadic occurrence, limited distribution, or their effect on the pine is relatively minor. But since we are looking into the future here, we can't overlook the possibility that some of these minor diseases may become serious at some later date. This development occurred with our three important diseases. The fungus which causes fusiform rust, identified in 1906, was considered to be of minor importance until about 1935, and since then is causing increasingly greater losses in our forests. The fungus associated with Brown spot was identified in South Carolina in 1876, but was not considered a serious disease of longleaf pine until 1919, a matter of 43 years. Fomes annosus, which is world-wide, was described in 1821, but the earliest report of concern over damage caused by this fungus which I could find was 1913, in Denmark. Since then, it appears to be increasing in severity both in Europe and in the United States.

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At present, only one of our three diseases can be prevented, temporarily. This is fusiform rust in nurseries and high-value plantations, such as seed orchards.

Here, "prevention" is the old familiar chemical control -- spraying the trees with a fungicide to prevent germination of the rust spores. It is of interest that Lamb and Sleeth made this recommendation in 1940, and except for minor refinement in methods and materials, there has been little change in the past 30 years.

I said the rusts can be prevented temporarily. It is a discouraging fact that the nurseryman can prevent all but an insignificant amount of rust by spraying, but the forester has no assurance that every healthy seedling he plants will not become infected in the next year or two.

Admittedly, the nursery and seed orchard are special cases. The trees are readily accessible and their value is relatively high, thus justifying intensive control measures. I doubt that we will ever see any attempts at rust control in natural stands, but prevention of severe losses in plantations certainly will be feasible in the future.

I can visualize a many-pronged approach to preventing rust in plantations. First, in the nursery, beginning with new, superior seed sources with inbred rust resistance in addition to other desirable characteristics. After germination, we will still spray the seedlings with a fungicide, but I believe this will be one or two applications, instead of 15 or 20 used at present. The fungicide will be long-term, persistent, and systemic, protecting the seedling through the critical first 4 or 5 years in the field.

After the nursery, there will be a program of applied ecology -- fitting the seedling to the site, and making the site unfavorable to the fungus. Briefly, site selection and preparation. We know the sporidia which infect the pines are produced during periods of high humidity, and usually at night. Avoid planting sites on low bottoms, or near streams and bodies of water. High humidities develop rapidly on such sites, and persist for longer periods of time. Also, avoid planting on slopes leading to streams. Night breezes carry the spores upslope. Poison the oaks on the site, and at the edge of the planting, and if possible, make a dense windbreak planting around the pine site, to intercept spores.

It is an expensive planting so far, but these are valuable, superior trees. We will have refined methods of predicting when the possibility of rust infection is high, and formulae for deciding whether to apply fungicides by helicopter at these times; something similar to the fire danger meter now in use.

Even now, and especially in the future, I believe it is a sound policy to selectively remove any rust infected pines from the plantation -- either as a TSI operation, sanitation thinning, or during any prescribed thinning. If conditions are even moderately favorable for the fungus, the aeciospores from one gall may be able to produce a heavy infection on the leaves of 10 oak trees, and these in turn supply the spores to infect thousands of pines.

Preventing mortality and growth loss of longleaf pine as a result of brown spot infection can be accomplished now, if we are willing to pay the price. Two applications of a fungicide per year, and a prescribed fire to destroy infected needles, will keep brown spot infection to tolerable levels. At present, we have only the conventional chemicals, such as Bordeaux mixture, or Fermate. We are still looking for the ideal fungicide I mentioned in discussing fusiform rust -- a persistent, systemic fungicide.

There is still quite a bit we don't know about the action of the fungus in producing brown spot symptoms. We do know that there are resistant strains of longleaf pine, and we will depend more and more on new seed sources to reduce the incidence of brown spot. Site selection is not as important as for fusiform rust, but the vigor of the seedling has a definite relationship to resistance. A well-nourished plant is less affected by brown spot, and grows out of the grass stage sooner.

Preventing loss from Fomes annosus root rot is more difficult in terms of the procedures available to us now or in the future. This is because the trees which are infected are those which were planted 20 to 30 years ago. I'm afraid that genetics cannot help us with this disease.

Present infections and mortality can be reduced by stump treatment with borax or urea at the time of thinning, and exercising care to prevent injury to the residual trees. There are indications that prescribed fire one or two years prior to thinning a stand will reduce the spread and severity of annosus root rot. We are not sure whether the burning affects Fomes annosus itself, or stimulates competing microorganisms, or influences soil moisture by promoting the growth of grasses and other herbaceous ground cover. This study is continuing.

We can begin now to reduce losses in the future by site selection prior to planting. For the deep south, at least, annosus root rot is more severe on deep sandy soil which had been in cultivation at one time or another. This is related to organic matter content, and possibly to the water holding capacity of the soil. By avoiding sandy, former agriculture soils with low organic matter as planting sites, we can prevent much of the future losses from root rot.

# COMANDRA BLISTER RUST

R. D. Wolfe [1/]

Comandra blister rust, caused by *Cronartium comandrae* Pk., is a canker disease of hard pines. The fungus is native to North America and until recently has been considered a problem only in the western and north central areas of the United States. However, recent surveys by the Division of Forest Pest Control have revealed commandra rust to be well established and causing considerable damage in two widely separated areas in the South; on the Cumberland Plateau in eastern Tennessee and northeastern Alabama, and the Ozark and Ouachita Mountains in northern Arkansas.

In the South, *Cronartium comandrae* has been reported on the following pine hosts: loblolly, *Pinus taeda* L., Virginia, *P. virginiana* Mill., pond, *P. serotina* Michx., and shortleaf, *P. echinata* Mill. (Berry et al. 1961; Cordell et al. 1969; Powers et al. 1967; Powers 1969).

In addition to pines, the fungus requires a second host to complete its life cycle. The alternate host in the South is *Comandra umbellata* (L.) Nutt., subspecies *umbellata* Piehl., a small herbaceous plant, often referred to as false toadflax or comandra.

*Tennessee* -- Comandra rust was first detected in eastern Tennessee in 1951 on planted loblolly and ponderosa (*P. ponderosa* Laws.) pine on the Bledsoe State Forest. The disease was probably introduced into the area on infected ponderosa pine planting stock (Powers et al. 1967).

In 1966, a preliminary survey was conducted by the Southern Forest Experiment Station, with assistance from the Division of Forest Pest Control, to determine if comandra rust was spreading to adjacent loblolly pine plantations on the Cumberland Plateau. Results of this survey revealed the disease to be present in several areas on the Plateau along with an abundance of the alternate host plants (Powers et al. 1967).

Thousands of acres on the Plateau were planted in loblolly pine by various private companies during the late 1950's and early 1960's. The concern expressed by the companies toward the new rust prompted the Asheville Office, Division of Forest Pest Control, to conduct a systematic survey of 19 Cumberland Plateau Counties in 1967. The objective of the survey was to determine the incidence of comandra rust in one to ten year old loblolly pine plantations.

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Results of the survey revealed the disease to be present in four additional (total of eight) counties in eastern Tennessee. The total number of plantations examined during the survey was 30, with 12 (40%) stands found infected with the rust. Approximately six percent of all the trees examined (2, 250) were infected; 1/3 of which were dead (Cordell and Knighten 1969).

In 1968, the Asheville Office, Division of Forest Pest Control, established 40 permanent 1/10 acre plots in 20 infected plantations on the plateau. The objectives of establishing these plots were to determine the annual rate of C. comandrae spread and mortality within one to 15 year old loblolly pine stands. An attempt will be made to correlate the data obtained from the plots to climatic and site factors (Cordell et al. 1969).

Results of the 1st Annual Remensurement in 1969 revealed an increase in infection of 1.4% (13.1% to 14.5%) with an increase in mortality of 1.2% over the previous year.

In 1969, the Tennessee Division of Forestry, (Mr Hart Applegate, I&DC Specialist), with the assistance of the Division of Forest Pest Control, conducted a fringe area survey in eastern Tennessee. The objective of the survey was to determine the incidence of comandra rust in areas outside the previously known range of the rust. Thirty-six plantations in 12 counties were surveyed. Results of the survey revealed no infections outside the known infected area, indicating that C. comandrae is confined to the gross area infected prior to 1969.

Therefore, in Tennessee, comandra rust is presently known to occur in eight counties of the Cumberland Plateau; widely scattered throughout a total of 38 loblolly pine plantations.

Arkansas -- The first report of C. comandrae in northern Arkansas was in 1962 on direct seeded shortleaf pine growing on the Buffalo District, Ozark National Forest (Dooling et al. 1964).

A biological evaluation of the disease was initiated by the Pineville Office, Division of Forest Pest Control, also in 1962. Three permanent evaluation plots (having a total of 702 shortleaf pine stems) were established in the infected area. Results of the five-year evaluation, concluded in 1967, revealed a cumulative pine mortality of 44% (309 stems). Disease intensification within the plots increased sharply from 1962 to 1964. Thereafter, new infections decreased each year until near stabilization in 1967. The decrease in new infections was attributed to the effect of crown closure on the survival of the alternate host.

Conversion of hardwood stands to pine on the Buffalo and surrounding Districts has continued since 1958. Thousands of acres have been converted through the use of aerial applications of herbicides, followed by direct seeding to shortleaf pine. Occasional reports from the Buffalo District of a canker disease on shortleaf pine, in areas close to the previously rust infected area, prompted a survey for the disease.

In 1968, the Pineville Office conducted a survey for comandra rust throughout the Ozark National Forest. The survey was restricted to planted or direct-seeded shortleaf pine stands of one to ten years in age. A total of 104 randomly selected pine stands were examined; 19 percent (20 stands) of which were found infected with C. comandrae. The disease was found on all eight Districts of the Ozark National Forest. The incidence of rust infection ranged from a trace (less than one percent) to more than 27 percent. Pine mortality, as a result of stem cankers, ranged from one to 19 percent (Wolfe et al. 1968).

In 1969, a similar survey was conducted on the Ouachita National Forest in central Arkansas and Oklahoma. From a total of 276 shortleaf pine stands, one to ten years of age, 61 percent (169 stands) were selected at random for field examination. Results of the survey revealed only one stand infected with C. comandra, located on Danville Mountain, Fourche District; having 68 percent infection and four percent mortality. This infected stand is approximately 15 miles from the closest known rust infected area, located on Magazine Mountain, Ozark National Forest (Wolfe et al. 1969).

Apparently environmental conditions are very favorable for infection and spread of this disease throughout Arkansas, unlike the conditions in the western United States where comandra rust infection occurs at infrequent intervals. Both plantations and direct seeded stands were found diseased; however, approximately twice as much infection and mortality was observed in direct seeded areas than in plantations.

Comandra blister rust has demonstrated its ability to severely damage and kill both loblolly and shortleaf pine in eastern Tennessee and northern Arkansas. In both areas, the disease is well established and will continue as a potential problem as long as susceptible pine hosts are used for regeneration purposes.

Therefore, in an effort to determine the relative susceptibility of other pine species to the rust, the Division of Forest Pest Control, The University of Tennessee, and the Tennessee Division of Forestry have initiated a cooperative test of eight pine species. The evaluation was started in

1969 with the planting of loblolly, pond, shortleaf, virginia, slash, red, white, and Japanese black pine in an area known to contain the alternate host plants. The plantings are located on the University of Tennessee's Highland Rim Experimental Forest, near Tullahoma, Tennessee. This susceptibility test will be carried on for the next five years, and may possibly reveal a pine species more resistant to comandra rust than loblolly pine.

The Asheville Office and the Tennessee Division of Forestry will continue to gather data from the 40 permanent evaluation plots established in 20 loblolly pine plantations on the Cumberland Plateau. As previously stated -- the objectives of this evaluation are to determine the annual rate of rust infection and mortality over a five year period. The effect of shading on the alternate host plants, climatic, and site factors will also be evaluated.

During the spring of 1970, the Alexandria Office, Division of Forest Pest Control, will initiate a five year evaluation of the disease in planted and direct seeded shortleaf areas on the Ozark National Forest in Arkansas. The objectives are to determine the annual rate of infection and mortality caused by the rust. The use of aerial infra-red color photography will also be tested as a means of evaluating the disease in known infected stands.

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PANEL ON HARDWOOD INSECTS AND DISEASES


Panel on Hardwood Insects and Diseases - L to R, R. G. McAlpine, Southeastern Forest Experiment Station, Athens, Georgia; H. H. Galusha, Crown-Zellerbach Corporation, Bogalusa, Louisiana; T. W. Jones, Pathologist, Northeastern Forest Experiment Station, Delaware, Ohio; R. C. Morris, Entomologist, Southern Forest Experiment Station, Stoneville, Mississippi; K. H. Knauer (Moderator), Hardwood Entomologist, Asheville, North Carolina.

# WHAT ABOUT HARDWOOD INSECTS?

Robert C. Morris [1]

Some seventy hardwood species achieve commercial importance in the South, and insects damage all of them in varying ways and to greater or less extent. The aim of the Forest Service's entomology research at Stoneville, Mississippi, is to develop biological, autocidal, and chemical controls for protecting trees of all ages. And these controls must be socially acceptable: they must check harmful insects without damaging the environment or injuring other animal and plant life.

The task obviously is tremendous, and to avoid spreading ourselves too thin we have concentrated on three groups of insects: (1) large trunk borers, especially the carpenterworm, *Prionoxystus robiniae*; (2) insects affecting the form of young trees, especially the cottonwood twig borer, *Gypsonoma haimbachiana*; and (3) defoliators, principally the forest tent caterpillar, *Malacosoma disstria.*

I will summarize our main findings on these pests and briefly mention plans for the near future.

## Carpenterworms

The adult carpenterworm is a large dark gray moth. The female lays eggs in bark crevices or near wounds in the trunk or large limbs; oaks are the favored trees. The newly hatched larvae make their way through the bark and enter the wood, where they tunnel for a year or two before maturing.

Early studies showed that spraying tree trunks in June with water emulsions of a persistent insecticide, BHC, would prevent new attacks, though it would not kill larvae already in the trees. The method is of limited applicability, however, for each tree must be sprayed annually and the chemicals are undesirable for wide use.

The unmated female moths produce a very effective sex attractant. In tests, marked males released in the forest have flown up to a mile to return to unmated females in cages on oak boles. If the attractant can be synthesized or otherwise produced in large quantities, it may offer a means of preventing the insect from reproducing.

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Studies have been undertaken to obtain quantities of female moths and develop methods for extracting the attractant for study and testing. Semiartificial diets have been formulated and the insects reared from eggs to adults in the laboratory. Field methods whereby moths are reared in caged trees have also provided several hundred adults each year. At present some 7,000 larvae are caged in oaks on the Delta Experimental Forest, near Stoneville.

Quantities of the sex attractant have been sent to cooperating chemists of the Agricultural Research Service at Beltsville, Maryland. Fractions have been returned to us for testing by exposure to male moths. While we still have a way to go before the attractant can be identified and synthesized, the work is promising.

If male carpenterworm moths can be attracted and captured, they can readily be sterilized. Recent tests in which males walked upon surfaces treated with a chemo-sterilant resulted in sterility within 2 hours. Thus it should be possible to capture large numbers of wild males in cages baited with the attractant or with unmated females, then sterilize and release them to fly to wild females in the forest. Since females mate only once, any that choose a sterile male will lay sterile eggs. In effect, the insect would limit its own population in an autocidal system that should not affect other wildlife or contaminate the environment.

Cottonwood Insects

Young cottonwood trees in nurseries and plantations are seriously damaged by borers and defoliators that injure the terminal tissue and thereby cause malformation of the stem and stunted growth. Conventional spraying is ineffective, for rapid growth constantly exposes new tissue to attack.

Soil applications of a systemic insecticide, phorate, protect planted cuttings during the first growing season and, if repeated as side dressings, during the second and third years. The organo-phosphate systemics are very toxic, but use of automatic dispensing hoppers on cultivating equipment will be developed to increase the safety of application. Several new systemics are now in test.

Several organo-phosphates and carbamates are being tested as ultra-low-volume (ULV) sprays in cottonwood plantations. In 1969, for example, tractor-mounted mist blowers applied 8 and 14 ounces per acre on 1,100 acres of first-year trees for control of the cottonwood leaf beetle, *Chrysomela scripta*. Results were good.

## Forest Tent Caterpillar

The forest tent caterpillar is probably the leading insect pest of sweetgum and water tupelo. Larvae hatch in spring and devour the new leaves. Trees later refoliate, but attacks in successive springs slow growth and, especially in sweetgum, may cause dieback.

Some natural controls exist. Field collections and laboratory rearings from eggs, larvae, and pupae have yielded four hymenopterous egg parasites, several tachinid parasites of larvae, and sarcophagid parasites of pupae, especially *Sarcophaga houghi*. A polyhedral virus disease of the larvae is widespread, as are two or more larva-killing fungus diseases. These natural agents apparently help to keep the caterpillars at a low endemic level throughout most of the Midsouth. In the water tupelo swamps of southwest Alabama and southern Louisiana, however, heavy defoliation has occurred annually since 1953 -- in Louisiana some forest workers have observed damage for more than 40 years. Adjacent sweetgum forests are also attacked. While the damage to sweetgum varies from year to year, the tent caterpillar can fairly be said to be a bad pest of three and one half million acres of forest land in these two states.

Permissible chemical controls must be harmless to the fish and wildlife in the river bottoms, swamps, and lakes of the infested areas. The testing of several organo-phosphate and carbamate insecticides has been initiated. These substances are of low initial hazard and break down in about 5 days after release. They can be aerially sprayed in small amounts, such as 12 ounces or 0.75 pint per acre. In preliminary trials during 1969 no ill effects on fish or wildlife were observed by biologists during and one day after the spraying, or by game wardens later.

## What's Ahead?

Our main work for the next few years will be to advance the three lines of research I have just described.

The ULV sprays are being tested again this year in the tupelo stands of southern Alabama. If they prove out, we will rely for their further development on the Branch of State and Private Forestry, whose Division of Forest Pest Control has been observing and aiding the work so far. The hope is that our 1969 and 1970 data, plus information gathered by the Division in pilot-scale trials, will justify registration of some of the chemicals for use in forests of the South.

While it is generally conceded that repeated defoliation slows tree growth, the amount of loss is a matter of opinion. Studies now being installed in Alabama and Louisiana will measure differences in diameter growth of defoliated and nondefoliated trees over a five year period. Water tupelo, swamp blackgum, and sweetgum trees will be included. Results should help gage the economic impact of the tent caterpillar and thus provide a rational basis for appraising control measures.

We will continue work with systemics by testing new chemicals, determining the best time for application, and developing recommendations for economic use in large plantations and in nurseries.

The autocidal control of the carpenterworm by sex attractants and sterilization will be advanced as rapidly as possible. The studies will be expanded to include the cerambycid borers of oak and cottonwood and the aegeriid clearwing borers in several other hardwood species.

There are some tempting possibilities for extending present lines or undertaking new research -- not a surprising situation, when one considers the scope of hardwood insect problems in relation to the number of researchers working on them. We are going to examine some of these possibilities.

Natural, or at least nonchemical, controls must be given more attention. We plan surveys to identify the natural enemies of the chief borers and defoliators, including the plantation pests of cottonwood. The role of birds as predators will be studied.

Red maple and sycamore are not defoliated by the tent caterpillar in the South. Studies will be undertaken to learn if extracts of maple and sycamore foliage contain substances that are naturally toxic or repellent to the insects. If such substances can be identified, perhaps they could be sprayed onto tupelo and sweetgum foliage.

Another broad subject is the effect of management practices on the size and composition of insect populations. When inferior trees are deadened or removed, will attacks on crop trees increase? Will trees stimulated by fertilization be unusually susceptible or resistant to insects? Do trees with inherent resistance exist, or can they be bred?

The acreage in hardwood plantations can be expected to expand rapidly. In monoculture, a forest manager may encounter insects that go virtually unnoticed in mixed stands. Cottonwood will probably be the favorite hardwood planting species for some time, and its insect problems have

been reasonably well defined, if not finally solved. Sycamore will be tried increasingly, and we intend to have some entomological information in hand when plantation acreage of this species begins to expand. We would like to make a start on cherrybark oak, sweetgum, and ash.

Three insects of elms, two of them the vectors of serious diseases, are beginning to appear in the Lower Mississippi Valley. The smaller European elm bark beetle, *Scolytus multistriatus*, brings with it the Dutch elm disease. The elm leafhopper, *Scaphoideus luteolus*, is associated with phloem necrosis. Somewhat less destructive, but still serious, is the defoliating elm leaf beetle, *Pyrrhalta luteola*. These pests are threatening large volumes of timber, and studies will be initiated to determine their behavior under southern conditions and, it is hoped, to devise controls or checks.

These, then, are our present research intentions. In the next 5 years we hope to accomplish most of them and to make at least a good beginning on the rest. It is risky to set research schedules, but it is also risky not to set them. Our rate of progress will depend on staffing and support, on the assistance of cooperators, and most of all on the difficulties presented by the subjects themselves.

## WHAT ABOUT HARDWOOD DISEASES?

Thomas W. Jones [1/]

I have been asked to talk today about diseases of hardwoods and, in keeping with the "Look Ahead" theme of this meeting, to speculate on problems of the future and how they may be dealt with. As a starting point let's consider the diseases of hardwoods that are now important.

### Heart Rots

Heart rots are by far the most damaging agents that affect our forest stands today. By reducing net growth and increasing mortality, they account for an annual loss of 3.4 billion cubic feet of wood. This is 80 percent of the total loss to all forest diseases. Three principal factors are responsible for the magnitude of the heart rot problem.

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The first of these is fire. A study of heart rots in oak stands in Ohio, Kentucky, Indiana, Illinois, and Missouri revealed that 75 percent of all decay columns originated at fire scars. Forty-five percent of the monetary loss following the average fire in eastern hardwood stands is due to heart rot that develops from the fire scars. Once heart rot organisms are established, they continue to invade and break down heartwood as long as the entrance wound is open. When the entrance wound heals, the decay fungi (probably because oxygen supply is reduced), generally become dormant. Since the ultimate size of the decay column is affected by the size of the wound, fire severity is important, as well as fire incidence.

Second is the past and, to a lesser extent, current practice of high-grading stands. When decayed trees are left standing after logging, they not only occupy growing space, but also increase the proportion of cull volume in the remaining stand. In some stands more than 40 percent of the timber volume is in rotten cull.

Third is the large volume of decay in old trees. The concept of pathological rotation limit is well established for such species as aspen and balsam fir, but is not well defined for many other hardwood species. It will vary between species and between sites, but generally rotations in excess of 100 years invite heavy losses to decay.

Other elements also influence the heart rot situation. These include wounds made in logging operations, wounds resulting from wind and ice breakage, natural pruning that leaves large branch stubs, and, in stands of sprout origin, decay entering from the parent stump.

Basal wounds made in skidding operations are just as effective entry points for decay fungi as fire scars.

Wounds made in the crown by falling trees may also be invaded by decay organisms, but most of these wounds are smaller and are in a less valuable portion of the tree. The same is true of some wind and ice damage -- although a tree with a completely broken top generally becomes a total loss.

Branch stubs large enough to contain heartwood, are -- entry points for decay fungi -- second in importance only to fire scars. Their importance is greatest in species that tend to retain their branches, such as scarlet oak and pin oak, and in stands where low density favors branch retention.

Hardwood stands of sprout origin are no more subject to decay than stands of seedling origin if the sprouts are from seedling stumps or originate from buds at or below ground line on small stumps. Sprouts originating above ground line on larger stumps are readily invaded by heart rot from or through the parent stump.

We know that losses to heart rots are heavy, but we also know how to reduce them tremendously. Since so many infections follow injury by fire, the obvious solution is to keep fire out of hardwood stands. As fire damage goes, so, in large measure, go heart rot losses. Improved management practices that provide for harvesting trees before they become decadent, that maintain stocking levels that encourage branch abscission and minimize ice and storm damage, and that provide for the removal of defective and high-risk trees in intermediate and harvest cuttings, will further reduce these losses.

Even-aged management, utilizing clearcutting to regenerate stands, is being practiced more generally with some hardwood species. This method, when applicable, can be particularly effective for reducing cull losses. Rotation age is more easily controlled; with no residual stand after harvest, logging injury is virtually eliminated; and felling culls is an integral part of the regeneration recipe.

Not too many years ago heart rot losses in pine stands averaged about 20 percent. Fire protection and improved management have reduced that loss to about 2 percent. The same practices can contribute greatly to the soundness of future hardwood stands.

## Diebacks and Declines

The group of diseases that are called diebacks and declines have attracted increasing attention in recent years. They include oak decline, sweetgum blight, cherry gummosis, and dieback of birch, maple, ash, yellow-poplar, and other hardwoods. The causes of these diseases, which affect such diverse tree species, are complex and poorly understood. Insect damage, root rots, and other pathogens, acting singly or in concert, are frequently implicated as contributing or major factors. They do appear to have the common characteristic of only affecting trees under physiologic stress. This stress is often attributed to drought; but a general warming trend in the climate since 1900, with attendant changes in storm patterns, onset and duration of spring and autumn, and temperature extremes, could also be important.

Oak decline is the name that has been applied to a widespread dying of scarlet and post oaks on poor sites since the early 1960's. All affected trees suffered from prolonged moisture stress. In some areas, the drought situation alone was severe enough to cause tree mortality. In other areas, defoliation by insects intensified and extended the damage. An in still other areas, Armillaria root rot, normally considered a weak parasite, became established in the root systems of weakened trees and finished off some that might otherwise have recovered.

Birch dieback was the most devastating disease in New England since the chestnut blight. It caused losses in 1952 of 494 million board feet. The causes for this decline in birch stands in this country and Canada are poorly understood, but there is little doubt that reduced rainfall and abnormally high temperatures are implicated. There is also evidence that a virus is involved, and the bronze birch borer has added to the damage by killing dieback-weakened trees.

A canker-causing organism is associated with recent widespread dieback of ash. This fungus, Cytophoma pruinosa, is a weak parasite and does not successfully attack vigorous trees. It appears that some widespread environmental change has resulted in reduced host vigor, allowing damaging outbreaks by this organism, which normally is of little importance.

Armillaria root rot is believed to play a role in a number of dieback and decline syndromes. We have known very little about how this normally weak parasite becomes damaging except that successful attack is usually limited to stressed trees. Current research by Dr. Houston of the Northeastern Station is shedding some light on the processes involved. He has learned that, after defoliation or drought, a tree's starch reserves are converted rapidly to soluble sugars, especially glucose and fructose. This is significant because Armillaria mellea readily metabolizes glucose and fructose and produces rhizomorphs, the organs responsible for infecting living trees. Sucrose, the principal sugar found in healthy trees, is poorly metabolized by the fungus; and starch, in concentrations occurring in healthy trees, is limiting to fungus growth.

It is not entirely clear whether dieback and decline problems are becoming more prevalent or whether we are just becoming more aware of them. In any case, I feel sure they will continue to plague us in the years ahead. We have little to offer in the way of control recommendations other than the old platitude of managing stands to maintain maximum vigor. As we learn more and apply more of what we already know of the site requirements and site limitations for hardwood species -- getting the right tree on the right site -- the impact of such diseases can be reduced.

## Vascular Diseases

Vascular diseases of forest trees include oak wilt, Dutch elm disease, persimmon wilt, mimosa wilt, sapstreak of maple and verticillium wilt of maple, elm, oak, box elder, horse-chestnut, and yellow-poplar. Of these, only oak wilt is considered an important forest problem.

Oak wilt has been among the most highly publicized forest diseases of the nation. It is caused by an aggressive tree-killing pathogen to which all oak species tested are susceptible and is considered a threat to the oak resources in the 21 states where it is known to occur. How valid or serious this threat may be is debatable. The disease has been known in this country for at least 30 years and probably has been here even longer. In that time, it has been responsible for rather negligible damage, and it is possible that natural factors may prevent its ever causing heavy losses in many areas. However, I know of no pathologist who is openly willing to write off oak wilt as a minor disease. Its importance lies in the fact that it is a tree killer, that it attacks our most valuable hardwood species, and that it could gradually build up to serious proportions over much of our oak timberland.

Two states, Pennsylvania and West Virginia, have vigorously pursued well-organized, statewide oak wilt control programs for more than 15 years. Oak wilt detection in both states is accomplished by repeated aerial and ground surveys. In Pennsylvania, diseased oaks and healthy oaks within 50 feet and of the same species group as the diseased tree are felled, and the stumps are poisoned with Ammate. Diseased trees are felled to hasten drying and reduce the number of fungus mats produced between the bark and wood. These fungus mats are a source of inoculum for spread of the fungus by Nitidulid beetles. Surrounding healthy trees are cut to prevent root-graft spread. This also eliminates the nearest suspects for aboveground spread of the fungus.

In West Virginia, diseased trees are girdled to the heartwood; and the bark -- from the girdle to ground line -- is removed. This hastens drying of the tree and prevents or reduces the formation of fungus mats.

The effectiveness of these programs has been appraised by special studies since 1958. The conclusions drawn from these appraisals may be of interest to you.

In these studies, the rate of oak wilt spread on untreated check plots has been greater in Pennsylvania than in West Virginia. However, over the years, these rates of spread have shown no tendency to increase.

The Pennsylvania control method has reduced spread of the fungus on study plots by 90 percent. But this excellent degree of control has been accomplished at a high, and perhaps unacceptable, cost in healthy trees destroyed. About seven healthy trees are cut for each diseased tree treated, and this may be more than would be lost to the disease if no control were attempted.

The West Virginia control method has reduced spread of the fungus on study plots in the southern part of the state by 79 percent but has had no beneficial effect on study plots in the northern part of the state. The overall degree of control may not be great enough to justify the cost of the program.

These studies have provided a good measure of the effect of both control treatments on fungus spread in the immediate vicinity of known infection centers. Unfortunately the plots proved to be too small to provide a valid appraisal of the effect of the programs on long-distance spread of the disease organism. Economic justification of either program may well hinge on how well they control this long-distance spread. Therefore a modified study employing extremely large plots was started last summer. Objectives are to compare oak wilt incidence in large areas where control treatments are applied with similar large areas where no control treatments are applied, to measure the relative importance of local and long-distance spread in treated and nontreated areas, and to gain some insight into the potential for damage by the wilt disease in large areas where no control is attempted.

Some recent developments in another area of our oak wilt research are perhaps noteworthy. It has been known for some time that Nitidulid beetles transmit the wilt fungus. This process requires the presence of fungus mats as a source of inoculum, and wounds made by some other agent for infection courts. Oak bark beetles have also been vector suspects, but the data to support this suspicion have been fragmentary.

We now have conclusive evidence that oak bark beetles, Pseudopityophthorus sp., meet the requirements for a vector of the oak wilt fungus in Missouri, Ohio, Pennsylvania, and West Virginia. They make breeding attacks on nearly all wilt-infected trees, often in large numbers. Many parent adults, as well as their progeny, leave the diseased tree, and some are contaminated with propagules of the fungus. They readily feed on healthy oaks, making wounds that are ideal infection courts for the fungus. Bark beetles will overwinter in wilt-killed trees and the fungus will remain viable overwinter in the bodies of bark beetle larvae, pupae, tenerals, and adults. Contaminated beetles emerge in April and

May, and feed on healthy trees. This time of year may be particularly critical because oaks are most susceptible to infection in the spring and we believe most natural infection occurs at this time. Infection does occur when contaminated beetles feed on healthy trees.

The number of other diseases of hardwoods that I might discuss is almost limitless. I have not touched on Dutch elm disease, nor on the important areas of foliage diseases, nursery diseases, and cankers. However, I would like to make a few general comments.

## The Responsibilities

One facet of our responsibility as forest pest research and control specialists is damage appraisal. This important function has not received the attention it merits. Damage appraisals, derived through valid and adequate survey or sampling procedures, are available for few, if any, forest diseases; and such estimates are often based on subjective observations. Most estimates of future damage are no more than educated guesses. I suspect that all this is also true for insect pests.

This situation can and should be corrected. Reliable damage information is vital to rational allocation of forest pest research and control resources. To an increasing degree we are being called upon to justify our existence, and valid damage figures are the best justification statements I know of. Also, I feel that the resource manager needs, and has the right to expect, more accurate estimates of current and future losses to forest pests than we are now providing. Improving our competence in this area will very likely require the combined efforts of pathologists, entomologists, economists, statisticians, control specialists, and others; but it can be done if we just recognize the need and get on with it.

Finally, I am sure that all of us are aware of the tremendously increased interest and influence of the general public in how public and even private timberlands are managed. Management goals and how we achieve them are being vigorously challenged; and it seems essential that ever greater consideration be given to esthetic, recreational, watershed, wildlife, and similar values. We in forest pest research and control organizations must also re-examine our objectives and methods in light of these values, if our work is to remain relevant and worthy of support.

For example, I believe we need to reappraise the importance of many diseases, judging them by values other than their impact on timber production alone. Some diseases, now considered of minor importance, will acquire much greater stature in recreation areas or areas of high scenic value.

The controversy over nearly all aspects of chemical control of pests is complex, and we do not have time to discuss it here. It does seem evident that we must start thinking of chemical control methods as a last resort rather than our first line of defense. On the other hand, I believe we can approach pest control with new and broader concepts of what is practical and economically feasible. Practices that would be ridiculous to recommend for large areas managed primarily for timber production may be readily justified on special-use areas.

If I have seemed to minimize the importance of timber production in these last remarks it was not intentional. Protecting the productivity of forest stands is, and I am sure will continue to be, our primary concern. But we must also recognize these other protection needs as valid and respond to them, or the responsibility for them will pass to other hands.

## PROBLEMS IN REGENERATING COTTONWOOD

Henry H. Galusha, Jr. 1/

Crown Zellerbach entered the cottonwood business in 1958 with the establishment of the St. Francisville Paper Company, a joint venture with Time Incorporated at St. Francisville, Louisiana. To help insure a continuing supply of cottonwood pulpwood, necessary for the manufacture of high quality printing papers, Crown Zellerbach's southern timber operation assumed the responsibility of establishing and managing the company's cottonwood plantations. The first cottonwood trees were planted in 1959 on the millsite at St. Francisville. In 1960 Fitler Plantation, a 15,000 acre tract in the Mississippi Delta, about 35 miles north of Vicksburg, Mississippi, was purchased. Fitler was once a cotton and cattle plantation. Since 1959, with the counsel of the personnel at the Southern Forest Experiment Station at Stoneville, Mississippi, more than 15,000 acres of cottonwood have been planted on company lands along the Mississippi River, almost 13,000 acres are at Fitler, making it the largest cottonwood plantation in North America.

To plant cottonwood successfully you must start with a cleared site and cultivate at least through the first year as cottonwood is intolerant of competition from weeds and vines. Through the years various techniques, equipment and spacings have been tried and today a fairly standard method of site preparation, planting and cultivation has evolved.

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1/ Management Forester, Crown Zellerbach Corporation, Bogalusa, Louisiana

The site is cleared, the brush piled and burned and then re-piled and burned again. It is then disced and raked at least once before planting. A crawler tractor pulling a subsoiling chisel is used to cut narrow trenches about 17 inches deep and 10 feet apart. These trenches are crossed with a fire plow at 10 foot intervals. The subsoiler facilitates putting the cuttings in the ground and also helps to break up any hard pan that may be present. Cottonwood cuttings are obtained from a number of sources, the Louisiana and Mississippi Forestry Commission nurseries, company nursery, other companies and from natural reproduction along river bars. The 20 inch cuttings, 3/4 to 1-1/4 inches in diameter, are planted by hand where the subsoiler and fire plow crossed resulting in a 10 X 10 spacing or about 435 trees per acre.

Cultivation with regular farm tractors is started as soon as weeds and grass begin to emerge. Straddle cultivation with chisel plows is used when possible until the trees get too tall, otherwise, scratchers or discs are used. A field is usually cross-disced five or six times and hand hoed once during the first year.

Growth has ranged from sensational to something less than satisfactory. At Fitler one research plot grew over 6 cords per acre per year while some areas may never reach this volume in total production. Some 2 year old trees are 4 inches in D. B. H. and 30 feet tall. There are trees 12 to 14 inches D. B. H. and 80 feet tall in the oldest plantations. Over the past 9 years, first year height growth has averaged 8 to 10 feet and survival has been about 65 percent. Average growth during the past year was something over 2 cords per acre.

Plans are now to manage cottonwood plantations on a 15 year pulpwood rotation with the first thinning at age 5. The cut has averaged about 3.75 cords per acre in these initial thinnings. Current practice is to clear-cut every fifth row and selectively cut the four remaining rows taking out the surpressed, crooked and defective trees. Clearcutting every third row has also been tried. General observation indicates that removing one-third to one-half the stem count is best.

Cottonwood is attacked by a number of insects. The two chief types of damage are boring in the twigs and stems and defoliation. The most troublesome as far as cottonwood regeneration is concerned, are probably the cottonwood twig borer (*Gypsonoma haimbachiana*), the cottonwood root and stem borer (*Paranthrene dollii*), a clearwing moth, the cottonwood borer (*Plectrodera scalator*), the poplar borer (*Saperda Calcarata*) and the cottonwood leaf beetle (*Chrysomela scripta*). *Cytospora*, *Phomopsis* and *Fusarium* cankers and *Melampsora* leaf rust are some of the more common diseases that infect cottonwood.

In the more than 10 years Crown Zellerbach has been planting cottonwood there have been some problems with insects and disease. Twig and stem borers have been a continuing problem. From 1960 to 1964 cuttings were treated with 44 percent phorate carbon dust before planting to protect the trees primarily from twig and stem borers. This practice was discontinued in 1964 because of the potential hazard in using this material. Now, except for the use of granular phorate in the clonal nursery at Bogalusa, no preventive treatments are used. Several years ago 500 to 600 acres at Fitler were sprayed with dieldrin to control the cottonwood leaf beetle. Infestations of this insect have occurred since but have not been serious enough to require treatment. In 1963 about 6500 acres at Fitler were infected with Cytospora canker. The diseased trees were 2 to 3 years old and 6 to 12 feet in height. Some areas were almost free of cankers while in others infection ran as high as 80 percent. By the end of the growing season almost all of the diseased trees had sprouted from the rootstock and were 8 to 10 feet tall. Except for some scattered infection in 1964, Cytospora has not been a problem since that time.

Results of the 1969 measurement of the continuous forest inventory plots at Fitler showed that slightly less than 2 percent of the trees measured showed evidence of insect damage, mostly by stem borers. When the plots were grouped according to stocking from poorest, 100 trees or less per acre, to the best, 300 or more trees per acre, the percent of insect damage for all categories of stocking but one was also about 2 percent. The number of infested trees in the 101 to 200 trees per acre class was 1.3 percent. The plots also showed that stocking and growth were related. By age class, the poorer the stocking the smaller the trees except for the two best stocking classes where there was little difference in tree size. The trees in the highest stocking category were slightly smaller in D.B.H. but somewhat taller. These results indicate that present degree of insect infestation is not related to stocking or growth. However, it should be pointed out that the trees are not measured until after the second growing season or later and we do not know what effect, if any, insects had on growth and stocking during the first critical years.

How important are insects and diseases as a problem in regenerating cottonwood? They can be a problem of course, but it is believed that there are more serious problems. Research has shown that growth can be increased by treating cottonwood with phorate to protect the trees from insects. However, even during the period that phorate was being used at Fitler poor growth and survival was a problem. This indicates that any benefit derived from the treatment was limited by other factors in some areas. Cottonwood is extremely sensitive to site. In the same plantation growth may be excellent in one place and very poor only a short distance away. In addition to site, other factors such as drought,

wet weather, inferior planting stock, flooding and vegetative competition have been observed to cause poor growth and survival. Analysis of the C.F.I. plots show that growth and survival is correlated with the degree of flooding and vegetative competition. In general, the lower the level of stocking the higher the degree of flooding and vegetative competition. Studies are currently underway to find methods to increase survival and growth in these areas.

What part do insects and disease play in these problem growth areas? As brought out above we have not really observed the effect during the first year or two. Available information indicates that there is little difference in the incidence of insect attack in the older trees. It is generally thought that slow growing trees are more susceptible to insect and disease attack and these agents may have more effect in these areas of poor survival and growth than we realize. Although the phorate treatment was not a cure all, it is possible that the situation in the poorer sites would have been worse had it not been used. For this reason we would like to use some treatment as effective as phorate, but one with less potential hazard, in initial plantings, especially in nurseries where borer damage often results in a large number of cuttings being culled.

With increased cottonwood plantings in the future and the consequent utilization of more of the poorer sites it is possible that insect and disease problems in the regeneration of cottonwood will become greater. Large areas of one species are usually more susceptible to infestations than smaller stands or stands of mixed species. The utilization of poorer sites can also lead to trouble unless methods to improve their productivity are developed. What effect these cultural practices, such as irrigation, fertilization and more intensive cultivation, will have is really not known. It is expected that, by increasing the rate of growth, they will reduce the insect and disease problem but it is possible that they could have the opposite effect. Studies underway or planned will help to answer this question. Genetics is another field receiving attention today. The development of strains resistant to insects and disease is an important factor to consider in genetic research.

In conclusion, insects and disease are a problem in the regeneration of cottonwood but they are far from being the most important one. Site and other factors which result in poor survival and growth are thought to be much more serious. Further research on these factors and in the field of genetics should solve the problem of growth and hopefully reduce the insect and disease problem at the same time.

# POTENTIAL PROBLEMS IN PRODUCING SILAGE SYCAMORE

Robert G. McAlpine [1/]

Before discussing the problems which may be associated with the growing, harvesting, and utilization of silage sycamore, it may be well to describe the concept and bring you up-to-date on those changes which have occurred over the past five years.

The proposed system, as first conceived, involved planting sycamore seedlings at close spacings in rows only 3 or 4 feet apart. Only the most productive sites would be planted; with cultivation and fertilization, high yields of fiber could be produced and trees could be harvested in relatively short rotations of two to five years. Harvesting would be accomplished by row-type silage harvesters. Thus, the derivation of the name "silage sycamore". Following harvest, the new crop would be regenerated by coppice.

At the outset, several important assumptions were made. The failure of any one of these would spell doom to the system. Among these were: (1) that juvenile sycamore could be used in the manufacture of paper, hardboard, and perhaps chip board without costly modifications; (2) that enough acreage in productive sites would be available to afford sustained production of sycamore chips throughout the year; (3) that sufficiently high yields of usable wood could be grown during a rotation period of two to five years to make the system economically feasible; (4) that machines could be engineered to harvest trees of a range of sizes from 1 to perhaps 8 inches stump diameter and 10 to 40 feet in height; (5) that regardless of cutting date, sycamore would resprout sufficiently well to assure a future crop; and (6) that plantings would remain relatively resistant to attack by organisms large and small, or that protective measures against these organisms could be devised.

At this time, it appears that most of our assumptions are valid. Tests of the suitability of young sycamore chips for the manufacture of certain types of paper, hardboard, and chip board show considerable promise. Measurements of plantations of seed origin indicate acceptable yields in green weight at ages four to six years and at spacings of 4 X 4 and 4 X 6 feet. The quality of bole wood of trees at these ages is acceptable for a variety of products, and the percentage of total weight of the tree represented by limbs and leaves is less than in younger trees.

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1/ Project Leader and Principal Silviculturist, Physiology and Culture of Piedmont Hardwoods, Forestry Sciences Laboratory, Southeastern Forest Experiment Station, USDA Forest Service, Athens, Georgia.

Although coppice information is limited, it appears that the increase in numbers of stems from sprouting will contribute to an increase in total weight per acre. A recent harvest of 2-year-old sprouts gave an increase of from 4 to 6 tons per acre over planted trees of the same age. An accompanying increase in number of dominant and co-dominant stems ranged from 9 percent at a spacing of 1 X 4 feet to 40 percent at 4 X 6 feet.

The Forest Service and the University of Georgia, in cooperation with several companies, have about 75 acres of experimental plantings. Represented are sites from the lower coastal plain to the Piedmont uplands, including bottomlands along Piedmont rivers and creeks. Although sycamore achieves its best growth on the latter sites, plantations on good upland sites have survived and grown almost as well when cultivated and fertilized. Plantations in some areas of the coastal plain seem to be doing well following intensive site preparation, cultivation, fertilization, and, in some cases, bedding. These low country areas, however, are not normally considered sycamore sites.

We knew that sycamore would usually sprout well. However, we were concerned that cutting trees in late summer and early fall might lead to frost kill of succulent sprouts. Also, there was some concern that cutting during the growing season could tend to reduce the amount of carbohydrates stored in the root systems. The relation of time of cutting to sprouting and subsequent growth is being studied in several experiments now underway.

Engineers concerned with design and manufacture of silage harvesters have assured us that machines can be designed and built to harvest young trees in much less time than it will take to perfect the system for growing the trees. Certainly, much larger and more sophisticated machines will be needed to harvest four- and five-year-old trees than those presently used by farmers. However, the principles may be similar.

The last and possibly the most important assumption is that we can cope successfully with the problems posed by insects, disease organisms, and animals. Although we know of some insects and diseases which are presently associated with sycamore, we are largely ignorant of the damage which they might do under an exaggerated system of monoculture such as we propose.

There appear to be only a few insects that directly cause a significant amount of damage to sycamore. The sycamore lacebug (Corythucha ciliata) causes premature defoliation or severely impairs the function of leaves so that growth is retarded. We have experienced difficulty

with the lacebug in the greenhouse, but have seen little damage in plantations. Mature trees in natural stands were heavily infested during the past growing season.

In young sprouts, occasional damage by the stalk borer (Papaipema nebris, Guen., family Noctuidae) has been noted. This caterpillar kills the tops of individual sprouts but seldom are infestation levels high enough to be of concern. The giant ragweed, commonly found in sycamore plantings, is the primary host for the stalk borer.

Perhaps of more importance in the culture of sycamore is an indirect effect of insect attack on young trees. Spores and mycelium of parasitic fungi often are carried by insects or become established in wounds caused by them. For instance, the periodic cicada appears to be the villain responsible for wounds in a number of young trees near Charleston, South Carolina, which are infected by a canker-causing pathogen as yet unidentified.

Often we can predict trouble to come by observing how insects attack other species being grown under similar circumstances. For instance, basket willow is grown in parts of Europe on short coppice rotations for its young sprouts which are woven into baskets. The concentration of large quantities of specific food in willow plantings has made possible the increase in population of several insects, including the poplar-and-willow borer (Cryptorhynchus lapathi L.).[1/]

This weevil causes damage to the growing shoot, thus rendering it useless in basket manufacture and to the stool which is often killed after two or three years infestation. Of interest to us is the fact that an insect which caused little damage in natural stands was able to build large populations and do considerable damage in plantations.

Our experience in planting sycamore leads us to believe that the species is relatively free of disease in our area of the South. Anthracnose (Gnomonia veneta) apparently does not like the climate of the deep South, and Texas root rot (Phymatotrichum omivorum) seems content to stay west of the Mississippi River. The shoestring root rot caused by Armillaria mellea attacks an occasional sycamore in natural stands but has not been found in our plantings. However, this rot is one which may cause trouble in the future.

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1/ Schnaider, A. 1962. Zwalczanie krytoryjka olszowca (Cryptorhynchus lapathi L.) w uprawach wierzb Koxzykarskich. (Control of the willow borer (Cryptorhynchus lapathi L.) in Osier plantations.) Prace Inst. Bad. Lesn. 249:225-250.

Potentially, the most important diseases are stem cankers. A stem canker of unknown cause but associated with Hypoxylon tinctor was reported on mature trees in a natural stand near Athens, Georgia. [1/] Although the canker killed a number of large, vigorous trees, it did not spread to a nearby plantation. Inoculation of planted trees with isolates from diseased tissue did not produce the canker. We feel, however, that this killer may appear again.

The canker-stain disease caused by Ceratocystis fimbriata f. sp. platani was found on one 6-year-old tree near Athens. Although it has not been found elsewhere, this disease is recognized as a killer and is particularly important because of our intention to use coppice regeneration.

Another stem canker (Diplodia natalensis), reported in the Athens area by Thompson[2/] in 1951 and later by Filer[3/] in the Mississippi Delta as Botryodiplodia theobromae, is of immediate concern. This organism has attacked and killed trees in a number of sycamore plantings in the lower coastal plain of South Carolina and Georgia.

Several diseased stems from a 2-year-old planting near Charleston, S. C., were flown to Athens for isolation and identification of the causal organism. From these, Dr. Ross[4/] obtained two isolates of B. theobromae and inoculated potted sycamore seedlings in March 1969. By January 1970, one isolate had caused cankers on 70 percent of the inoculated seedlings, but the other had caused none. This indicated possible differences in pathogenicity among isolates of B. theobromae. This same fungus was recently reported as causing cankers on about 10 percent of 2-year-old seedlings in a planting near Jesup, Georgia. [5/]

These reports are particularly distressing since the affected plantings had not been cut. It is quite possible, therefore, that the fungus will spread rapidly by infesting stumps left by the harvesting machine or the machine itself may actually spread the disease.

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1/ McAlpine, R. G. 1961. Hypoxylon tinctor associated with a canker on American sycamore trees in Georgia. U. S. Dept Agr. Plant Dis. Rep. 45:196-198.

2/ Thompson, G. E. 1951. Die-back of sycamore. U.S. Dept. Agr. Plant Dis. Rep. 35:29-30.

3/ Filer, Theodore H., Jr. 1965. Sycamore canker-pecky but not disastrous. Southern Lumberman 211(2632):169-170.

4/ Personal communication, Dr. Eldon Ross, USDA, Forest Service, Southeastern Forest Exp. Station, Forestry Sciences Laboratory, Athens, Georgia

5/ Personal communication, Dr. Klaus Steinbeck, School of Forest Resources, University of Georgia, Athens, Georgia. January 1970.

Thus far our limited experience has shown sycamore to be relatively free of damage by deer, beaver, and rodents. Only isolated instances of browsing by deer or cutting by beavers have been noted. Rabbits have been known to cut young seedlings, but these sprout readily. Of some concern is the sting nematode (Belonolaimus longicaudatus Rau.). This very small worm is found in farmlands of the lower coastal plain and according to Ruehle[1/] is capable of damaging the roots of sycamore seedlings. He suggested that a disease problem could arise if sycamore is planted on well-drained, sandy soils in the lower coastal plain.

When compared to other species in the South, sycamore seems to be relatively free of problems. Potentially the most damaging organisms are Ceratocystis fimbriata f. and Botryodiplodia theobromae which can cause stem cankers on seedlings and threaten to become epidemic in closely spaced coppice stands. It is likely that we can reduce the danger of infection by planting only the better sites and by using common sense sanitation methods. It should be a simple matter to engineer into the harvesting machine some form of automatic sterilization of cutting parts.

We have the ability to select not only fast-growing strains of sycamore, but those which exhibit some degree of resistance to disease. Sycamore can be vegetatively propagated with such ease that cuttings can be field planted with reasonable assurance of good survival. Good results have been obtained by planting one-year-old sprouts horizontally in furrows. This is a form of planting that can be easily mechanized.

With these facts in mind, and in spite of the problems mentioned here, we remain optimistic that the silage sycamore concept can be developed into a workable system.

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1/ Ruehle, John L. 1968. Pathogenicity of sting nematode on sycamore. Plant Dis Rep. 52(7):524-525.

# A P P E N D I X

# AGENDA
## SOUTHEASTERN AREA - STATE AND PRIVATE FORESTRY
## FIFTH FOREST INSECT AND DISEASE WORK CONFERENCE

Atlanta, Georgia
Atlanta Cabana Motor Hotel
Castilian Ballroom
February 17 - 19, 1970

THEME - A LOOK AHEAD

<u>Tuesday, February 17, 1970</u>

| | | |
|---|---|---|
| 8:00 - 9:00 | REGISTRATION | |
| 9:00 - 9:10 | INTRODUCTION | R. K. Smith<br>Ass't. Area Director |
| 9:10 - 9:30 | WELCOME | D. A. Craig<br>Area Director |
| | ANNOUNCEMENTS | |
| 9:30 - 10:00 | COFFEE BREAK | |
| 10:00 - 10:40 | Keynote Address | R. B. MacDonald<br>Purdue University |
| 10:40 - 11:00 | Challenge of the Seventies | D. E. Ketcham<br>Director, FPC<br>Washington, D. C. |
| 11:00 - 11:30 | What's New in Research | T. F. McLintock<br>Director, FPR<br>Washington, D. C. |
| 11:30 - 1:00 | LUNCH | |

<u>Tuesday Afternoon</u>

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| 1:00 - 1:30 | Industrial Needs in Pest Control | N. E. Johnson<br>Weyerhaeuser Co.<br>New Bern, N. C. |

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| 1:30 - 2:00 | Sensory Perception in Insects | P. S. Callahan<br>University of Florida<br>U. S. D. A. Lab |
| | PANEL - DETECTION | |
| | Moderator | W. M. Ciesla<br>Supervisor, FPC<br>Alexandria, Louisiana |
| 2:00 - 2:30 | Application of Remote Sensing in Future Surveys | J. C. Bell<br>Div. FPC<br>Asheville, N. C. |
| 2:30 - 3:00 | COFFEE BREAK | |
| 3:00 - 3:30 | Color Infrared Photography as an Indicator of Early Fomes Annosus Infection | G. N. Mason<br>Texas Forest Service |
| 3:30 - 4:00 | Using Radiography in Surveys | T. H. Flavell<br>Div. FPC<br>Asheville, N. C. |
| 4:00 - 4:30 | Detection in Florida | C. W. Chellman<br>Florida Forest Service |
| 4:30 - 5:00 | Training in Surveillance | C. R. Grady<br>N. C. Forest Service |
| 5:30 - 7:00 | SOCIAL HOUR | |

Wednesday, February 18, 1970

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| | PANEL - EVALUATION | |
| | Moderator | C. F. Krebs<br>Div. FPC<br>Atlanta, Georgia |
| 8:00 - 9:00 | Detection & Appraisal in Canada | R. S. Forbes<br>Forest Biology Lab.<br>Canada |

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| 9:00 - 9:40 | Southern Pine Beetle Population Behavior | R. T. Franklin<br>University of Georgia |
| 9:40 - 10:00 | Processing Survey Data | W. H. Clerke<br>Div. FPC<br>Asheville, N. C. |
| 10:00 - 10:30 | COFFEE BREAK | |
| | PANEL - AIR POLLUTION DAMAGE APPRAISAL | |
| | Moderator | D. D. Davis<br>Div. FPC<br>Alexandria, Louisiana |
| 10:30 - 11:00 | Detection of Air Pollutants in Forested Airsheds | F. A. Wood<br>Penn. State University |
| 11:00 - 11:30 | Air Pollution Indicators in Forest Stands | C. R. Berry<br>S. E. F. E. S.<br>Asheville, N. C. |
| 11:30 - 1:00 | LUNCH | |

Wednesday Afternoon

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|---|---|---|
| | PANEL - PREVENTION AND CONTROL | |
| | Moderator | G. L. Downing<br>Div. FPC<br>Atlanta, Georgia |
| 1:00 - 1:30 | Pilot Projects | J. L. Rauschenberger<br>Div. FPC<br>Asheville, N. C. |
| 1:30 - 2:00 | Removing Infested Trees by Commercial Sales | L. E. Drake<br>Div. FPC<br>Alexandria, Louisiana |
| 2:00 - 2:30 | Planning Salvage Operations Following Hurricanes | W. H. Echols<br>Mississippi Forestry Commission |

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| 2:30 - 3:00 | COFFEE BREAK | |
| 3:00 - 3:30 | Planning to Meet Ice Storm Disasters | J. E. Graham<br>S. Carolina Forest Service |
| 3:30 - 4:00 | Wood Products Insects | H. R. Johnston<br>S. F. E. S.<br>Gulfport, Mississippi |
| 4:00 - 4:30 | Pest Control in Urban Areas in the Future | J. W. Mixon<br>Georgia Forestry Commission |

Thursday, February 19, 1970

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| | PANEL - FOREST DISEASES | |
| | Moderator | W. R. Phelps<br>Div. FPC<br>Atlanta, Georgia |
| 8:00 - 8:30 | Tree Resistance in Insect and Disease Control | E. R. Roth<br>Div. FPC<br>Atlanta, Georgia |
| 8:30 - 9:00 | *Fomes annosus* in the Southeast | C. S. Hodges<br>S. E. F. E. S.<br>Raleigh, N. C. |
| 9:00 - 9:30 | Preventing Diseases in Pine Stands | F. J. Czabator<br>S. F. E. S.<br>Gulfport, Mississippi |
| 9:30 - 10:00 | Comandra Blister Rust | R. T. Wolfe<br>Div. FPC<br>Alexandria, Louisiana |
| 10:00 - 10:30 | COFFEE BREAK | |
| | PANEL - HARDWOOD INSECT AND DISEASE | |
| | Moderator | K. H. Knauer<br>Div. FPC<br>Asheville, N. C. |

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| 10:30 - 11:00 | What About Hardwood Insects | R. C. Morris<br>S. F. E. S.<br>Stoneville, Mississippi |
| 11:00 - 11:30 | What About Hardwood Diseases | T. W. Jones<br>N. F. E. S.<br>Delaware, Ohio |
| 11:30 - 12:00 | Problems in Regenerating Cottonwoods | H. H. Galusha<br>Crown-Zellerbach |
| 12:00 - 12:30 | Potential Problems in Producing Silage Sycamore | R. G. McAlpine<br>S. E. F. E. S.<br>Athens, Georgia |

ADJOURN

| | |
|---|---|
| Arrangements Chairman | E. R. Roth |

SOUTHEASTERN AREA - STATE AND PRIVATE FORESTRY
FIFTH FOREST INSECT AND DISEASE WORK CONFERENCE
February 17 - 19, 1970

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|---|---|---|
| Charles Affeltranger | Pathologist, Div FPC | Asheville, N. C. |
| Hugh I. Alford | Entomologist, N. C. Dept of Agriculture | Asheville, N. C. |
| Robert A. Anderson | Products Technologist Shell Chemical Company | Atlanta, Georgia |
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| Walter L. Beers, Jr. | Assoc. Staff Manager-Research, Buckeye Cellulose Corp. | Perry, Florida |
| Gary Bell | Timber Mgt. Staff | Gainesville, Ga. |
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| C. W. Chellman | Entomologist, Fla. For. Service | Tallahassee, Fla. |
| W. M. Ciesla | Entomologist, Div FPC | Alexandria, La. |
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| George L. Downing | Entomologist, Div FPC | Atlanta, Georgia |

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| Loyd E. Drake | Entomologist, Div FPC | Alexandria, La. |
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| Henry H. Galusha, Jr. | Mgt. Forester, Crown-Zellerbach Corp. | Bogalusa, La. |
| C. R. Grady | Staff Forester, N. C. Forest Service | Raleigh, N. C. |
| John E. Graham | Forest Mgt. Ass't. S.C. For. Comm. | Columbia, S. C. |
| Bill Gresham | Entomologist, Ark. For. Comm. | Harrison, Ark. |
| Berch W. Henry | Ass't Dir., FID SO. For. Expt. Sta. | New Orleans, La. |
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| Gerard E. Jacques | Timber Mgt. Staff USFS | Harrisonburg, Va. |
| F. F. Jewell | Prof., Forest Pathology La. Tech. University | Ruston, La. |
| Norman Johnson | Forest Research Supvr. Weyerhaeuser Company | New Bern, N. C. |
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| LeRoy Jones | Tree Improvement Chief, SA, S&PF | Atlanta, Georgia |
| Jay L. Jones, III | Entomologist, Texas For. Serv. | Lufkin, Texas |
| Thomas W. Jones | Pathologist, NE For. Expt. Sta. | Delaware, Ohio |
| David E. Ketcham | Dir., Forest Pest Control | Washington, D. C. |
| Doyle L. Kline | Staff Park Ranger, Nat. Park Serv. | Richmond, Va. |
| Kenneth H. Knauer | Hardwood Insect Entomologist, Div. FPC | Asheville, N. C. |
| John L. Knighten | Biological Tech., Div. FPC | Asheville, N. C. |

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| Charles F. Krebs | Biometrician, Div. FPC | Atlanta, Georgia |
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| Hoover L. Lambert | Biological Tech., Div. FPC | Asheville, N. C. |
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| H. Leland Moore | Entomologist, Ga. For. Comm. | Macon, Ga. |
| Caleb L. Morris | Chief, Insect & Disease Invest., Va. Div. For. | Charlottesville, Va. |
| Robert C. Morris | Entomologist, SO For. Expt. Sta. | Stoneville, Miss. |
| G. L. Nachod | Forester, La. For. Comm. | Woodworth, La. |
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| Robert Neelands | I&E, R-8 USFS | Atlanta, Ga. |
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| Howard B. Overton | Park Ranger, Nat. Park Serv. | Richmond, Va. |
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| Elmer R. Roth | Pathologist, Div. FPC | Atlanta, Ga. |

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| John M. Skelly | Ext. Spec., Plant Pathology, Va. Poly. Inst. | Blacksburg, Va. |
| Russell K. Smith | Ass't. Area Dir., FPC SA-S&PF | Atlanta, Ga. |
| Walter E. Smith | Timber Mgt. Staff, NF in N. C. | Asheville, N. C. |
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| Charles D. Turner | Ass't. Forester, Barksdale AFB | Bossier City, La. |
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| Michael Vinson | Ass't. Ranger, Cherokee NF | Tellico Plains, Tenn. |
| Huey Wallace | Biological Tech., Div. FPC | Alexandria, La. |
| James D. Ward | Entomologist, Div. FPC | Asheville, N. C. |
| Bob Wiese | Timber Mgt. Staff USFS | Hot Springs, Ark. |
| Robert D. Wolfe | Pathologist, Div. FPC | Alexandria, La. |
| Francis H. Wood | Assoc. Prof. Pennsylvania State University | University Park, Pa. |
| Harry O. Yates, III | Entomologist, SE For. Expt. Sta. | Athens, Ga. |

## ORGANIZATION
## DIVISION OF FOREST INSECT AND DISEASE CONTROL
## STATE AND PRIVATE FORESTRY, SOUTHEASTERN AREA

| Area Office - Atlanta, Georgia | |
|---|---|
| R. K. Smith | Entomologist - Asst Area Director |
| G. L. Downing | Entomologist, Branch Chief |
| W. R. Phelps | Pathologist, Branch Chief |
| E. R. Roth | Staff Pathologist |
| Lois J. Ament | Chief Clerk |
| Carol S. Cohen | Clerk-Typist |
| Evelyn M. Schlingloff | Clerk-Typist |

| Areawide Specialists | |
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| C. F. Krebs | Biometrician |
| J. C. Bell | Survey & Remote Sensing Specialist |
| K. H. Knauer | Hardwood Entomologist |
| D. D. Davis | Air Pollution Specialist |

| Zone 1 - Asheville, North Carolina | |
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| J. L. Rauschenberger | Entomologist - Zone Leader |
| P. J. Barry | Entomologist |
| W. H. Clerke | Entomologist |
| J. D. Ward | Entomologist |
| T. H. Flavell | Entomologist |
| P. P. Laird | Pathologist |
| C. E. Affeltranger | Pathologist |
| C. E. Cordell | Pathologist |
| H. L. Lambert | Biological Technician |
| W. E. McDowell | Biological Technician |
| R. F. Bassett | Biological Technician |
| E. T. Wilson | Biological Technician |
| J. L. Knighten | Biological Technician |
| Barbara C. Whitt | Chief Clerk |
| Charlotte A. Arledge | Clerk-Stenographer |
| Dorotha G. Barrett | Clerk-Typist |

| Zone 2 - Alexandria, Louisiana | |
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| W. M. Ciesla | Entomologist - Zone Leader |
| L. E. Drake | Entomologist |
| N. A. Overgaard | Entomologist |
| J. R. Terry | Entomologist |
| D. R. Kucera | Entomologist |
| R. D. Wolf | Pathologist |
| D. H. Wilmore | Biological Technician |
| P. H. Peacher | Biological Technician |
| H. N. Wallace | Biological Technician |
| J. R. Hyland | Biological Technician |
| Mary W. Hutchins | Chief Clerk |
| Patricia Adams | Clerk-Stenographer |
| Trina P. Foto | Clerk-Typist |

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STATE AND PRIVATE FORESTRY · SOUTHEASTERN AREA ·

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PROTECT

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**U.S. DEPARTMENT OF AGRICULTURE**